PHYSICOCHEMICAL, PHYTOCHEMICAL AND SENSORIAL QUALITY OF GUMMY CANDIES PRODUCED FROM MANGO (*Mangifera indica*) PEELS WITH DIFFERENT TYPES OF FRUIT SWEETENERS

BY

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ABSTRACT

PHYSICOCHEMICAL, PHYTOCHEMICAL AND SENSORIAL QUALITY OF GUMMY CANDIES PRODUCED FROM MANGO (*Mangifera indica*) PEELS WITH DIFFERENT TYPES OF FRUIT SWEETENERS

Chong Wai Yan

The increased consumer awareness of natural product consumption has increased the trend to develop confectionery products using natural ingredients, as their nutrition and functionality contribute to the properties of gummy products. The purpose of this study was to investigate the effect of using monk fruit, date fruit and table sugar (control) as sweeteners while utilising mango by-products (mango peels) in the production of gummy candies. Therefore, the physicochemical, phytochemical, and organoleptic qualities of three gummy candies were compared in this context. The gummy candy made with monk fruit sweetener (T1) was significantly different ($p < 0.05$) among three gummy candies in terms of total soluble solid content (45.3˚Bx), water activity (0.68) and colour ($L^* = 67.42$; $a^* = 1.92$) while moisture content (53.09%) and pH (3.82) were not significantly different ($p > 0.05$) from control in physicochemical properties. T1 has the highest total flavonoid content (680.00 µg QE/ml) while its total phenolic content (41.00 µg GAE/ml) and DPPH scavenging activity (61.47%) were lower than date fruit

sweetener gummy candy (T2). Furthermore, the results from the sensory evaluation showed significant differences in appearance and overall acceptability of T1, while aroma, taste and texture were not significantly different from control. This reflected that monk fruit sweetener can be potentially used as sweetener substitute in gummy candy products. This study also suggested that the date fruit sweetener can be used in nutraceuticals or functional foods other than gummies as a natural alternative sweetener due to its high phenolic and antioxidant properties. Freeze-dried mango peel powder can be further used to address fruit waste and increase the phytochemical and antioxidant properties of gummy candies.

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DECLARATION

I hereby declare that this final year project report is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTAR or other institutions.

CHONG WAI YAN

APPROVAL SHEET

This final year project report entitled **"PHYSICOCHEMICAL, PHYTOCHEMICAL AND SENSORIAL QUALITY OF GUMMY CANDIES PRODUCED FROM MANGO (*Mangifera indica*) PEELS WITH DIFFERENT TYPES OF FRUIT SWEETENERS"** was prepared by CHONG WAI YAN and submitted as partial fulfilment of the requirements for the degree of Bachelor of Science (Honours) Food Science at Universiti Tunku Abdul Rahman.

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PERMISSION SHEET

It is hereby certified that **CHONG WAI YAN** (ID No: **18ADB06388**) has completed this final year project report entitled "PHYSICOCHEMICAL, PHYTOCHEMICAL AND SENSORIAL QUALITY OF GUMMY CANDIES PRODUCED FROM MANGO (*Mangifera indica*) PEELS WITH DIFFERENT TYPES OF FRUIT SWEETENERS" under the supervision of Dr. Ong Mei Kying from the Department of Agricultural and Food Science, Faculty of Science.

I hereby give permission to the University to upload the softcopy of my final year project in pdf format into the UTAR Institutional Repository, which may be made accessible to the UTAR community and public.

Yours truly,

CHONG WAI YAN

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
AOAC	Association of Official Agricultural Chemists
$AlCl_3$	Aluminum chloride
*a**	Redness
*b**	Yellowness
CIELAB	International Commission on Illumination
DCPIP	2,6-Dichlorophenolindophenol
DPPH	2,2-Diphenyl-1-picrylhydrazy
FDA	Food and Drug Administration
Fe^{2+}	Ferrous ion
g	gram
GA	Gallic acid
GAE	Gallic acid equivalent
GRAS	Generally Recognized as Safe
GI	Glycemic index
HPO_3	Metaphosphoric acid
*L**	Lightness
M	Molarity
mg	Milligram
mL	Milliliter
mm	Millimeter

mM	Millimolar
nm	Nanometer
Na_2CO_3	Sodium bicarbonate
$NaCO_3$	Sodium carbonate
NaOH	Sodium Hydroxide
$NaNO_3$	Sodium nitrate
pH	Potential hydrogen
QE	Quercetin Equivalent
R^2	Multiple correlation coefficient
ROS	Reactive oxygen species
rpm	Revolution per minute
SD	Standard deviation
TFC	Total flavonoid content
TPA	Texture profile analysis
TPC	Total phenolic content
v/v	Volume per volume
w/v	Weight per volume
%	Percentage
˚C	Degree Celsius
˚Brix	Degree Brix

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Gummy jellies and candies are the most prominent and significant confectionery products in the candy market. They are widely made from a combination of sugar syrup and hydrocolloids (gelling agents such as gelatine and pectin), while the organoleptic properties differed depending on the percentage used in hydrocolloids and the moisture content in the gummy candies (Avelar, Queiroz and Efraim, 2020). Gummy candies made with gelatine account for around 50% of the confection market value as most of the customers prefer the texture such as chewiness and gumminess of the candies (Ahmed, 2015). However, in terms of utilisation rates, sweetening agents such as sucrose, glucose and corn syrups are the most crucial ingredients that bring the taste to the candies (Gok, et al., 2020). High sucrose concentration present in gummy candies might possess an adverse effect on health as the high glycaemic index will cause an increase in blood glucose levels. Additionally, often consuming high-calorie, high-glycaemic foods might cause postprandial glucose and insulin levels to rise excessively (Takeungwongtrakul, Thavarang and Sai-Ut, 2020).

In recent years of development of confectionery products, especially gummy candies, have claimed the term functionality, healthiness as well as fortified formulation on their packaging labels. The desire for more mindful, practical, wholesome and natural food options has grown in response to consumers' growing interest in eating a proper diet (Avelar, Queiroz and Efraim, 2020). It is crucial in improving the formulation, especially the application of sweeteners used in the gummy candies as the consumers' attitudes and behaviours have changed towards healthier food. The food industry and health-conscious consumers are constantly looking for ways to produce candy while still maintaining the product's texture, volume, flavour, shelf life and processability characteristics (Kurt, Bursa and Toker, 2021). The sugar used as a sweetener in the production of gummy candies can also influence the sol-gel transitions when it comes in contact with water and hydrocolloids, increases Brix, and promotes the caramelization and Maillard reaction. The major challenges in the sweetener replacement in gummy candies from Kurt, Bursa and Toker (2021) studies are the sweetness, solubility, effect on the structure of candy and the interaction with gelling agents.

Many researchers currently focus on alternative sweeteners to replace sugar in gummy candies such as the study done by Samakradhamrongthai and Jannu (2021) developed chewy candies by using stevia, xylitol and corn syrup; Rivero, et al. (2021) produced gelatine candies by using stevia and propolis; molasses as substitution of sugar in gummy candies production by Kurt, Bursa and Toker (2021)

and the production of gummy candies from corn syrup, honey and coconut palm syrup by Tan (2021).

Date fruit sugar and monk fruit sugar are the natural sweeteners that are found in the fruit as they can be used as a functional food to provide the necessary sweetness without adding extra calories, prevent a drastic rise in blood sugar levels, and have no negative side effects when consumed in long term (Pandey and Chauhan, 2019). Monk fruit sweetener originally comes from *Siraitia grosvenorrii* fruit and the mogrosides are the main active ingredient that provides the sweet taste to the fruit. Monk fruit has several advantages, including antioxidant and hypoglycaemic characteristics. It is also suitable for those on diets because it is a zero-calorie sweetener. Date fruit is found to be rich in protein, sugar, dietary fibre, mineral, vitamins as well a substantial amount of flavonoid glycosides while date sweeteners are claimed that are rich in phenols, α-glycosidase and α-amylase (Ahmed, Aljasass and Siddiq, 2014; Vayalil, 2012). Thus, it is significant to conduct research regarding the development of gummy candies produced by using different fruit sweeteners such as monk and date fruit sweeteners as there is lack of study among the researchers.

Besides that, fruit processing industries have accounted for more than 5 billion tons of waste and most of the waste are inedible components such as seeds and peels from the fruits. The by-products from the fruit waste are rich in bioactive

compounds such as dietary fibres, protein as well as phytochemicals and have the potential to be used as bioingredients in functional food and nutraceutical products (Coman, et al., 2019). Marçal and Pintado (2021) claimed that reusing mango peels in food production might increase revenue for mango processing industries and decrease the amount of biowaste that is disposed of. Ibrahim, et al. (2017) also stated that the research on fruit waste has recently gained popularity with the natural presence of antioxidant activity and polyphenols in the fruit peels. Pectin, lipids, proteins, carotenoids, cellulose, hemicellulose, vitamins, and polyphenols are found abundant in mango peel and have remarkable health-promoting qualities, especially antioxidant activity.

1.2 Problem Statement

The use of fruit waste from households become more popular nowadays as studies have shown that fruit peels are rich in phytochemicals and antioxidant properties. In this research, using mango (*Mangifera indica*) peels to make gummy candies can help recycle waste from the fruit and cut down on environmental pollution. As mango peels (by-product of mango) are not commercially used in production, they are being discarded as fruit waste and caused pollution to the environment (Kim, et al., 2009). This research investigates the uses of different types of fruit sweeteners (monk fruit and dates) to be incorporated into gummy candy to replace conventional table sugar in producing more healthy candy as nowadays many people are preventing the intake of refined sugar. Low glycaemic index in fruit

sweeteners consists of huge potential in the future, especially for children, diabetic and obese patients.

It has an obvious increase in sugar intake in food and beverages especially among the kid and teenagers around the aged of 4 to 18 and the increasing consumption of gummy candy can lead to health problems such as tooth decay, obesity, or hyperglycaemia because of the high glycaemic index (Edwards, et al., 2016). The food companies continued in using table sugar as their sweetener in confectionery due to the high cost of natural or fruit sweeteners compared to others. Sugar in the form of glucose, fructose and sucrose is usually used in enhancing the sweetness of the products by food and beverage manufacturers. Hence, health-conscious consumers are searching for alternative sweeteners in candy production in maintaining the texture, appearance, shelf life and overall acceptability of the products (Kurt, Bursa and Toker, 2021). There is more attention to those alternative sweeteners that provide positive health-promoting effects in the natural alternative sweeteners such as monk fruit sweetener as well as date sweetener.

The high demand for gummy candy has prompted the new formulation and fortification with different raw materials such as adding nutraceuticals and antioxidants into the products. Thus, this research is mainly focused on the addition of the mango (*Mangifera indica*) peels that come from the mango's fruit waste that is rich in phytonutrients such as carotenoids, vitamin E, vitamin C and polyphenols

as well as the replacement of the table sugar by fruit sweeteners into gummy candy production (Onuh, et al., 2017).

1.3 Purpose and Objectives

This research aimed to utilize the mango waste (peels) to incorporate into gummy candy with different fruit sweeteners (monk fruit and date fruit sweetener) compared with control (white sugar) to determine the physicochemical, phytochemical and sensorial properties between three types of gummy candies made with different sweeteners. Thus, the research focuses on the potential functional properties of mango peels and better alternative sweeteners for gummy candies. The objectives of this research are

i. To investigate the physicochemical of gummy candy produced from the mango (*Mangifera indica*) peels incorporated with different types of fruit sweeteners.
ii. To compare the phytochemical and antioxidant properties of gummy candy produced from mango (*Mangifera indica*) peels incorporated with different types of fruit sweeteners.
iii. To determine the acceptability of consumers on gummy candy produced from mango (*Mangifera indica*) peels with different types of fruit sweeteners.

CHAPTER 2

LITERATURE REVIEW

2.1 Sweeteners

Sweeteners are classified as food additives that are added purposely as tabletop sweeteners or to enhance the sweet taste of food. Tabletop sweeteners, including any permissible sweetener, are products designed to be sold to the final customer and typically used as a substitute for sugar (Varzakas, Labropoulos and Anestis, 2012). Sugar that is present in gummy candy is one of the main ingredients that provide a sweet taste, texture, preservative properties, and bulking effect as well as support the structure of the products (Lê, Robin and Roger, 2016). There are mainly two classes of sweeteners which are intensive sweeteners and bulk sweeteners while in the nutritional points of view, non-caloric, low-caloric and caloric were introduced (Bassoli and Merlini, 2003). Nowadays diabetic patients and diet-conscious often looking for alternative sugar that can replace sugar by reducing the calorie content in the products and this led to the new rising of alternative sugars among food and beverage companies. Alternative sweeteners can replace sugar by offering options for functional properties such as sugar intake and caloric control; weight management; treating diabetic concerns; preventing dental diseases; overcoming sugar deficits and sweetening costs (Varzakas, Labropoulos and Anestis, 2012).

The relative sweetness of the sweeteners is mostly depending on the total sugar level while a high concentration of sugar level increases the relative sweetness significantly (Tiefenbacher, 2017). The way sweetness is perceived is arbitrary and depends on a variety of factors such as the temperature of products, pH value, concentration of sweeteners and other raw materials in the products. Table 2.1 shows the relative sweetness of alternative sweeteners as compared to sucrose.

Table 2.1: Relative sweetness of alternative sweeteners (Nabors, 2001).

Sweeteners	**Relative sweetness (Sucrose: 1)**
Lactitol	0.4
Polyglycitol, maltitol syrups	0.4–0.9
Isomalt	0.45–0.65
Sorbitol	0.6
Erythritol	0.7
Mannitol	0.9
Xylitol	1.0
High-fructose corn syrup, 55%	1.0
Cyclamate	30
Glycyrrhizin	50-100
Aspartame	180
Lo han guo fruit extract	180

Table 2.1: Relative sweetness of alternative sweeteners (Nabor, 2001).

(continued)

Acesulfame K	200
Saccharin	300-500
Steviol glycosides	300
Sucralose	600
Thaumatin	2000-3000
Neotame	8000
Advantame	20000

Sucrose which acts as a golden standard is not an ideal sweetener as it is not suitable to be used in pharmaceuticals and chewing gums. For the ideal sweetener, it should have a similar sweet taste to sucrose, colourless, odourless and non-carcinogenic. Consumer acceptance is increased by an alternative sweetener's similarity to sucrose in both taste and function. Besides, the industry is more interested in sweeteners if they can be processed similarly to sucrose with the existing equipment. The ideal sweetener should possess water-soluble properties with high stability in both acidic and basic circumstances over a board temperature range (Nabors, 2001).

2.2 Types of Sweeteners

Nutritive sweeteners are defined as the sweeteners that can contribute energy and calories while non-nutritive sweeteners also known as high-intensity sweeteners can provide consumers with a means to experience the sensation of sweetness with little or without energy consumption and trigger a glycaemic reaction (Edwards, et al., 2016; Varzakas, Labropoulos and Anestis, 2012).

2.2.1 Nutritive Sweetener

The nutritive sweetener can be categorised into sugar (monosaccharides and disaccharides), bulk sweeteners as well traditional sweeteners which are naturally present in plant or animal sources. Glucose, fructose and galactose are three major sugars present in food and beverages while these sugars are also the major component in the high fructose corn syrup and table sugar. In the small intestine, nutritive sweeteners are normally hydrolysed into individual monosaccharides, which are then absorbed and metabolised to produce dietary energy that usually is 4 kcal per gram (Edwards, et al., 2016).

Another type of nutritive sweetener is polyols which are also called sugar alcohols and are present naturally in fruits, vegetables as well as fermented food. They are derived from saccharides which are hydrogenated from monosaccharides or disaccharides in the manufacturing process. Polyols (xylitol, sorbitol, maltitol and

erythritol) are prominently used as sweeteners especially in low-calorie food and beverages due to their poor absorptivity in the small intestine as well as yield lower calories and glycaemic responses compared to other nutritive sweeteners (Edwards, et al., 2016).

Traditional sweeteners also called unrefined sweeteners are natural, low-processed, and can be obtained from bees, fruits, or sap of plants. They are widely used in many countries as a primary sweetener due to their sources of sweetness in nature with the minimum processing (Edwards, et al., 2016). There are produced from several parts of the plant including sap, roots, nectar, flowers, leaves as well as fruits of the plants. The cane juice, maple syrup, palm sugar and maize sugar can be derived from the sap of plants and through drying and boiling, thus become more concentrated in syrup. Other examples are sugar beet syrup is from the roots of plants; watermelon sugar, pumpkin sugar and date sugar come from the fruits while *Stevia* spp. is from the leaves of plants (Varzakas, Labropoulos and Anestis, 2012). Traditional sweeteners are classified as nutritive sweeteners due to their high percentage of sugars such as sucrose, fructose and glucose. One of the benefits of consuming traditional sweeteners is the presence of nutritive compounds such as protein, dietary fibre, phytochemicals such as polyphenols as well as a minor amount of minerals and vitamins (Edwards, et al., 2016).

2.2.2 Non-nutritive Sweetener

Most non-nutritive sweeteners are artificial sweeteners that are synthesised chemically and have a huge potential in the market due to the small percentage used in the formulation can provide an equivalent sweet taste to nutritive sweeteners to the consumers. Non-nutritive sweeteners, also known as high-intensity sweeteners, are easily absorbed through the gastrointestinal tract and do not promote the blood sugar response (Edwards, et al., 2016; Varzakas, Labropoulos and Anestis, 2012). They are claimed to have at least 30 to 20,000 relative sweetness as compared to standard (sucrose) mentioned in Table 2.1 and these high-intensity sweeteners only require minor quantities to produce sugar-like sweetness in the food products (Shankar, Ahuja and Sriram, 2013). These properties can target the consumers who are in the treatment of obesity, diabetes control, body weight maintenance, as well as dental cavities prevention. Some non-nutritive sweeteners are permitted such as saccharin (E954), aspartame (E951), acesulfame K (E950), cyclamate (E952), sucralose (E955) and thaumatin (E957) (Varzakas, Labropoulos and Anestis, 2012). Although non-nutritive sweeteners do not release energy during digestion, they are not suitable for use in a wide variety of products due to unstable conditions in the manufacturing process and resulting in unpleasant organoleptic properties. Non-nutritive sweeteners are mostly artificial sweeteners that have their regulation on the amount to be consumed and might possess the concern related to human gut microbiota as they entered the large intestine without undergoing digestion in the small intestine (Varzakas, Labropoulos and Anestis, 2012). According to findings from multiple epidemiological research, consuming non-nutritive sweeteners may

raise an individual's risk of developing metabolic syndrome, type-II diabetes, and obesity (Pepino, 2015). In this context, nutritive sweeteners are more prominent to be used as the main sweeteners in the coming years although there is a wide range of usages of non-nutritive sweeteners in food and beverage manufacturing.

2.3 Date Fruit in Gummy Candy Making

2.3.1 Date Palm

Date palm (*Phoenix dactylifera* L.) is one of the Palm family (*Aceraceae*) and has been planted since antique times. The date palm can be grown up to 1500 metres above sea level on sandy soil with proper drainage (Tang, et al., 2013). Ashraf and Hamidi-Esfahani (2011) stated that it contains three parts which are the flesh with a light crust, date pits and the cap. Tang, et al. (2013) further stated that the fact of date fruit can supply the human energy boost and can be stored for a long period may be one factor encouraging the spread of date palms. It is the ideal nourishment for individuals like warriors on military missions, traders, and excavators traveling a great distance. Date fruit stands out for its special qualities since it may be eaten as a staple food all over the world and has remained an important part of people's diets for thousands of years (Vayalil, 2012).

2.3.2 Ripening Stage of Dates

There is a total of five stages involved in the formation and ripening process of date fruit such as *hababauk*, *kimri*, *khakak*, *rutab* and *tamer* while they involved intricate processes such as degradation of chlorophyll, carotenoid synthesis, disruption of the cell wall and conversion of starch into sugar (Ashraf and Hamidi-Esfahani, 2011). Figure 2.1 shows the formation and ripening of the date fruit.

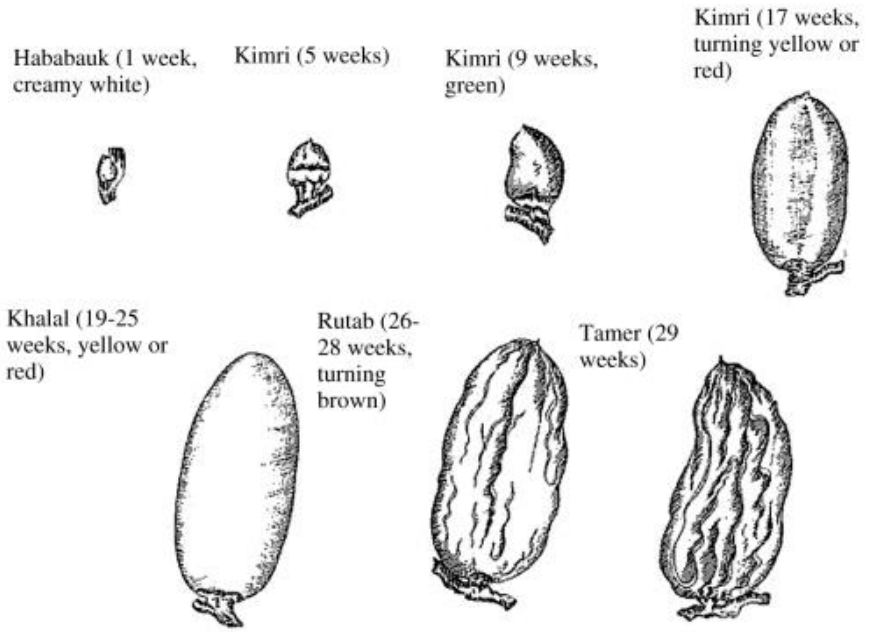

Figure 2.1: Formation and ripening of date fruit (Ashraf and Hamidi-Esfahani, 2011).

In the *hababauk* stage, the fruits are developed in round shapes and will continue to grow for 4 to 5 weeks after pollination happened. Date fruit in the *kimri* stage has a hard texture with the increasing tannin concentration as well as the increasing sugar content, acidity and moisture content after 17 weeks of pollination (Ashraf and Hamidi-Esfahani, 2011). While in the *khalal* stage, the yellow and hard texture of date fruit was observed with the greatest size with increasing sucrose formation. The dates start to ripe in the *rutub* stage as they are darker in colour, loss of water and form from the sucrose. Date fruit reach *tamer* stage in the last 2 weeks while the fruits are high in total soluble solid and sweetness as well as increasing the concentration of glucose and fructose with decreasing sucrose concentration (Ashraf and Hamidi-Esfahani, 2011).

2.3.3 Chemical Composition

Date fruit is rich in sugar, dietary fibre, protein, vitamins and minerals while a large amount of flavonoid glycosides, such as quercetin, *p*-coumaric acid, ferulic acid, apigenin, and sinapic acid, have been found in date fruit, according to recent studies (Ahmed, Aljasass and Siddiq, 2014). Dates have a fairly good nutritional profile overall when compared to other well-known dried fruits. Table 2.2 below shows the main chemical composition of date fruit and the relative percentages present.

Table 2.2: Main chemical composition of date fruit (Ashraf and Hamidi-Esfahani, 2011).

Composition	Quantity percentage (%)
Sugar	44–48
Water	5–20
Protein	1–7
Fat	0.1–0.5
Pectin	1–4
Ash	1–2.5
Crude fibre	3–18
Polyphenol	3

2.3.3.1 Carbohydrates

Date fruit is rich in carbohydrates mostly in simple sugar forms such as glucose and fructose. Dates that contain around 75 g of carbohydrates, or 18% of the recommended value for carbohydrates in 100 g serving, based on the USDA National Nutrient Database while the glucose to fructose ratio is approximately equivalent (Ahmed, Aljasass and Siddiq, 2014). According to Ashraf and Hamidi-Esfahani (2011), glucose, fructose, non-reducing sugar (sucrose), and a trace amount of polysaccharides like starch and cellulose are present in the date fruits. Based on the research done by Al-Farsi and Lee (2008), the average sugar content of fresh dates is 22.8, 19.4 and 4.03 g/100 g for glucose, fructose and sucrose while

30.4, 29.4 and 11.6 g/100 g are recorded for glucose, fructose and sucrose respectively in dried fruit. This can prove that the total soluble solid content is raising continuously from *kimri*, *khalal*, *tamer* stages and this is highly related to the reduction of moisture content in these stages (Ashraf and Hamidi-Esfahani, 2011).

2.3.3.2 Fibres

Cellulose, hemicellulose, insoluble proteins and lignin are the insoluble solid parts majority found in date flesh that is called fibre or crude fibre (Ahmed, Aljasass and Siddiq, 2014). Crude fibre is the by-product of plant cell extraction during acid and alkaline hydrolysis (Ashraf and Hamidi-Esfahani, 2011). The total fibre contents raised from 7.5 g/100 g from fresh dates to 8.0 g/100 g dried dates due to the reduction of moisture and dates ripening which the enzymes eventually break down these molecules into the more soluble chemicals that soften the fruit. Producing a high amount of liquid date sugar, it is required a low amount of fibre with moisture while pre-treatment with extracted juice with pectinase can increase the yield in liquid sugar (Ashraf and Hamidi-Esfahani, 2011).

2.3.4 Phytochemical Composition

Phytochemicals, a class of bioactive non-nutrients, are thought to be responsible for the fruits' preventive properties against chronic diseases. Due to their cholesterol-lowering abilities, antioxidant activity and other potential health

benefits like the chemoprevention of cancer, the prevention of diabetes, and the prevention of cardiovascular illnesses, phytochemicals have drawn the attention of more researchers, including professionals (Vayalil, 2012). Several kinds of bioactive components, including carotenoids, particularly phenolic acids, isoflavones, lignans, flavonoids, polyphenols, tannins, and sterols, are found in date fruit. The amount and phytochemical composition of date fruits vary greatly depending on the maturation stage, storage, postharvest processing, variety of dates, degree of moisture, experimental settings utilised for the analysis, and the region from which the dates were harvested (Vayalil, 2012). Based on the research done by Vayalil (2012), after sun drying process, the total phenolics (22–153%) and phenolic acids (64–107%) of date fruits increase dramatically while decreasing in total carotenoids (up to 30%) and anthocyanins (93%) content.

2.3.4.1 Carotenoids

Carotenoids make up most of the phytochemicals in the lipid fractions of date fruits. As the date fruit ripens from *khalal* to *tamar* stages, it has been observed the total carotenoids content has declined rapidly while the most dominant carotenoids found are β-carotene and lutein (Ahmed, Aljasass and Siddiq, 2014; Vayalil, 2012). Ahmed, Aljasass and Siddiq (2014) further justified the deterioration of carotenoids because moisture content has been lost in date fruits during the ripening process while it is presumably unrelated to the browning of date fruits.

2.3.4.2 Total Phenolics

Phenolic compounds are among the most significant bioactive substances and are known for their ability to operate as strong antioxidants and free radical scavenging activity which serve as reducing agents and hydrogen donors. There are found to include *p*-coumatic, sinapic acid and the cinnamic acid derivatives present in most of the fruit of the ripe date (Ahmed, Aljasass and Siddiq, 2014). Vayalil (2012) has reported that the total amount of phenols that are present in the different varieties of dates vary depending on the different types of date fruits. The dried date fruits are found to have the greatest concentration of polyphenols among most dried fruits when exposed to high temperatures such as sun drying compared to other fruits. The presence of tannins in date fruit can aid in colour development during ripening and storage from the browning reaction (Ashraf and Hamidi-Esfahani, 2011).

2.4.4.3 Antioxidants

Dates fruit has good sources of antioxidants as it can suppress the oxidative processes that cause degenerative diseases like arthritis, heart disease, and cognitive malfunction. According to the study Ahmed, Aljasass and Siddiq (2014), dates can stimulate the immune system, govern the function of antibiotics, and have anticancer and antimutagenic effects. They can also reduce the risk of cancer, particularly pancreatic cancer. The extraction from date flesh was reported to have dominancy in free radical scavenging activity to reactive oxygen species such as hydroxyl and superoxide radicals. The antioxidant activity has a strong correlation

with the total phenolic content of date fruit as the increasing of phenolic content can increase antioxidant activity while the percentage of antioxidants differ with dates' phenolic compounds, carotenoids, and flavonoids as well as vitamins C and E. The high antioxidant properties perceived in date fruit are the potential to serve as functional food ingredients in food products (Ahmed, Aljasass and Siddiq, 2014).

2.3.5 Date Fruit Sweetener

Dates fruit sweetener is manufactured by grinding dehydrated dates into a powder that has the consistency of granulated sugar which is called granulated sugar, with its darker colour and stronger flavour make it a superior substitute for brown sugar (Kaminsky, 2022). It can simply replace the table sugar by substituting with the ratio 1:1 of table sugar to date fruit sweetener and give a similar sweetness compared to table sugar. Pena-calderon (2021) stated that date fruit sweetener consists of whole date fruit including the date pits, resulting in the difficulty to be dissolved in water as the presence of date pit provides a fibrous grit texture.

The study by Vayalil (2012) showed that date fruit sweetener was found to have the highest antioxidant activity among a variety of carbohydrate sweeteners, which was closely correlated with the phenolic content of the sugars by using 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay. Besides that, date sweetener is phenol-rich, powerful antioxidants, and effective α-glycosidase and α-amylase inhibitors

(Vayalil, 2012). Date sugar has been found to have the highest antioxidant activity among the various sugars examined, and this activity is closely correlated with the total amount of phenolics present and the inhibitory activity against the formation of DPPH radicals. The high blood glucose level in type-II diabetes can be controlled by α-glycosidase inhibitors while α-amylase is a potent pharmacological drug that has the function of anti-diabetic (Vayalil, 2012). Oligosaccharides, disaccharides and trisaccharides are unable to break down to glucose in the small intestine due to the presence of α-glycosidase inhibitors that hinder the hydrolysation pathway of membrane-bound intestinal α-glycosidase while the conversion of starches into oligosaccharides is inhibited by pancreatic and salivary-amylase inhibitors. Less glucose is taken into the blood as these enzyme systems' inhibition slows down the pace of carbohydrate digestion (Vayalil, 2012).

2.4 Monk Fruit in Gummy Candy Making

2.4.1 Monk Fruit

Siraitia grosvenorii (monk fruit) also called "Luo Han Guo" in Chinese originated from the Cucurbitaceae family and is indigenous to Guangxi Province in southern China, while Guilin's mountains produced most of the products (Jin and Lee, 2012; O'Donnell and Kearsley, 2012). Traditional Chinese medicine has utilised this species to treat dry coughs, sore throats, extreme thirst, and constipation by acting as a pulmonary demulcent and emollient. The ripe fruit extract is widely marketed

as a supplement and a component in health foods and beverages to replace sugar as a non-sugar sweetener since its fruit contains glycosides that are naturally sweet and low in calories. As a result, *S. grosvenorii* is receiving more scientific and business attention (Jin and Lee, 2012).

According to O'Donnell and Kearsley (2012), W.T. Swingle published the first scientific identification of *S. grosvenorii* in 1941 using plants gathered in southern China. In honour of the president of the National Geographic Society, Dr. Gilbert Grosvenor, which is also a sponsor of acquiring monk fruit in China, Swingle gave the plant the scientific name *Momordica grosvenorii.* The new information revealed that the plant's proper name should be *S. grosvenorii* (Swingle) C Jeffrey (O'Donnell and Kearsley, 2012).

2.4.2 Chemical Composition

There are several chemical compositions found in *S. grosvenorii* with the main compositions which are triterpenoids, especially flavonoids, cucurbitane-type triterpenoid glycosides, protein, polysaccharides (glucose and fructose) as well as essential oils (Li, et al., 2014). Among the chemical compositions, cucurbitane-type glycosides are the major components and the active ingredient found in *S. grosvenorii* (Li, et al., 2014). Jin and Lee (2012) stated that these triterpene glycosides were originally emphasised in the chemical investigations of *S. grosvenorii* due to their sweetness and pharmacological activity. From the fruit of

S. grosvenorii, 26 different varieties of cucurbitane-type triterpene glycosides, 3 different cucurbitane-type triterpene aglycones alcohol, 2 different forms of pentacyclic triterpene and 3 different triterpene benzoates have been isolated and characterised. Li, et al. (2014) further justify the cucurbitane glycosides share the same structure which is mogrolaglycone [10α-cucurbit-5-ene-3β, 11α, 24(*R*), 25-tetraol] attached with two to six glucose units. They are classified as mongrosides due to the sweetness present in *S. grosvenorii* while the mongrosides percentage in the dried *S. grosvenorii* is doubled that of fresh *S. grosvenorii* (Li, et al., 2014). The sweetest taste among the cucurbitane glycosides is siamenoside while 0.5 to 1.4% of mogroside V is the main component that present in dried *S. grosvenorii*. To compare the sweetness of monk fruit with sucrose, one part per ten thousand of mogroside V and siamenoside I have 425 and 563 times sweeter than 5% of sucrose subsequently (Li, et al., 2014).

Li, et al. (2014) explained that some of the structures of glycosides are responsible for sweetness taste in *S. grosvenorii* such as the function of oxygen at 11-position of aglycone moiety, a unit of glucose molecules, side chain hydroxylation and location of glycosyl unit. This can be related to the fact that the sweetest molecules among the glycosides in *S. grosvenorii*, siamenoside I, which has four glucosyl units, and mogroside V, which has five glucosyl units, both have different structures (Li, et al., 2014).

2.4.3 Benefits of Monk Fruit

2.4.3.1 Antioxidant Effects

The free radicals are hyper-reactive due to unpaired electrons that bind to the surrounding atom to start chemical reactions while antioxidant is the potential to scavenge free radicals and quench pro-oxidants in the body. Monk fruit possesses antioxidant properties and inhibits the formation of superoxide (Suri, et al., 2020). Gong, et al. (2019) studied the scavenging activity of mogrosides by using the chemiluminescence method toward reactive oxygen species (ROS) and the result showed the antioxidant properties found in crude extracts of *S. grosvenorii* are as high as ascorbic acid content. Mogroside extract efficiently removes free radicals, lowers the frequency of haemolysis of Fe^{2+}, and minimizes the oxidative stress to hepatic tissues brought by hydrogen peroxide (Gong, et al., 2019).

2.4.3.2 Hypoglycaemic Activity

According to Suri, et al. (2020), the primary active component of *S. grosvenorii* that causes its hypoglycaemic effects is called mogroside. Zero-calorie sweeteners of monk fruit can regulate the blood glucose level in the body efficiently by mogrosides which increase postprandial insulin levels while preventing the conversion of dietary sugar. The authors continued to claim that mogroside V has shown promising results in preventing tissue damage and muscle atrophy by

improving glucose utilisation and body weight, as weight loss and polyphagia are often associated with the onset of diabetes (Suri, et al., 2020). Currently, the primary hypoglycaemic mechanisms of *S. grosvenorii* include intestinal α-glucosidase activity inhibition, pancreatic damage repair, insulin secretion stimulation, free radical scavenging, and anti-lipid peroxidation (Gong, et al., 2019).

2.4.4 Ideal Replacement for Sweetener

Monk fruit sweetener is established to use in food and beverage companies by Food and Drug Administration (FDA) as Generally Recognized As Safe (GRAS) but still pending to be approved in Europe as food additive among food companies. FDA states that the sweetener is safe for use by diabetics, pregnant women, and children (Hadjikinova, 2022). The relatively low glycaemic index in monk fruit (GI = 20) increases its suitability to become an alternative sweetener with zero calories, especially for obesity and diabetic patients. The authors also emphasised the sweetness as it possesses 150 to 300 times sweeter than sucrose while it has a less bitter taste compared to high-intensity sweeteners such as acesulfame K and saccharin (Hadjikinova, 2022). Mogrosides have a mogrol backbone, which is connected to a glucose unit by a glycoside link at its C3 and C24. The upper gastrointestinal tract does not absorb the compounds and commit zero calories in food or beverage while glucose units are broken by microbes in the colon as energy sources.

Water extraction is normally implemented in the manufacturing of monk fruit extract (Younes, et al., 2019). There are different percentages of mogrosides V in monk fruit extracts from 25 to 95% but the most commercial percentage is 55% mogrosides V (NutraSource, 2017). The purification processes that result in varying concentrations of mogroside V content account for the majority of the differences in how the diverse monk fruit extracts are made (Younes, et al., 2019). Fry (2012) briefly stated the manufacturing process of monk fruit sweetener. Firstly, *S. grosvenorii* where fry drying to preserve and provide a smoke note to the fruits. The fresh *S. grosvenorii* were crushed and extracted with de-ionised water for 30 to 40 minutes at 80˚C. The protein or larger molecules were eliminated by using an ultrafiltration membrane when the supernatant is cooled at 50˚C. The monk fruit extract is processed by the adsorption resins, which allow for the approval of undesired chemicals such as reducing sugars while rejecting the organic materials (particularly mogrosides) (Fry, 2012). The resin is eluted with aqueous ethanol, and the eluent is then decoloured after being partially concentrated at low pressure. The liquor is then further concentrated to produce the final product, which can alternatively be spray-dried at 120°C to create a monk fruit powder. The final product has about 40% soluble solids (Fry, 2012).

2.5 Mango Fruit

2.5.1 Background of Mango Fruit

According to Martin and He (2009), mango (*Mangifera Indica* L.) is the Anacardiaceae family's most economically valuable fruit and originated in Asia, namely the Indo-Burmese region, around 4000 years ago. Evergreen mango trees that reach a height of around 18 metres and bear fruit four to six years after planting are preferred by tropical and subtropical regions. Mangoes are the fifth most produced major fruit crop around the world and are second only to bananas in terms of quantity and value among tropical fruits exported internationally. Over 26 million tonnes of mangoes are believed to be produced annually in the world (Martin and He, 2009). Maldonado-Celis, et al. (2019) and Martin and He (2009) stated that mango fruit is not only rich in carbohydrates, protein, and organic acid, but it also consists of the non-nutrient compound such as phenolic compounds (mangiferin, quercetin, catechins, kaempferol gallic acid), flavonoids as well as carotenoids.

2.5.2 Health Benefits of Mango Fruit

Other than macronutrients as stated above, vitamins A, B and C in mango fruits play an important role in supplying essential dietary requirements as stated by WHO/FAO (2003) (cited in Maldonado-Celis, et al., 2019). Vitamin B such as

thiamine (B1), riboflavin (B2), niacin (B3) and so on are being found in mango fruit that beneficial for human health. Shah, et al. (2010) further stated that vitamin E and β-carotene in mango fruits might be beneficial to prohibit some chronic diseases as it is ten times higher β-carotene in ripe mango compared to unripe mango. The phytochemical compounds found in mango fruits can contribute to overall flavour and colour while leucocyanidin, epicatechin, catechin, chlorogenic acid and quercetin are the primary phenolics found in mango fruit (Kabir, Shekhar and Sidhu, 2017). According to Swaroop, et al. (2018), the mangiferin present in mango fruit chemically called 2-C-β-D-glucotyranosyl-1,3,6,7-tetrahydroxyxabthen-0-one exerts pro-hypoglycaemic effects via modifying insulin resistance, reducing cholesterol production, altering glucose metabolism, and suppressing the production of TNF and inactivating nitric oxide synthase. The presence of antioxidants in mangiferin noticeably increased in pro-inflammatory and inflammatory situations such as infections and diabetic disorders (Swaroop, et al., 2018).

2.6 Mango Peels

Martin and He (2009) claimed that mango peels are a significant by-product of mango products' manufacturing with rich sources of bioactive compounds. Mango peel and pit are discarded during processing making up around 15% to 20% of the fruit weight and it might be treated as a unique product due to its high concentration of phenolic residue. The total polyphenolic content of dried mango peels was shown

to be around 4066.0 mg/kg, the dietary fibre content in mango peels of various types was assessed to be 16–28% soluble dietary fibre, 29–50% insoluble dietary fibre, and 45–78% total dietary fibre respectively (Martin and He, 2009). Mango peels have a significant number of gallic acid and its derivatives such as flavonoids, catechins, benzophenones and gallotannins (Oliver-Simancas, et al., 2021).

2.6.1 Bioactive compounds

According to Jahurul, et al. (2015), there are two primary bioactive compounds present in mango peels which are ethyl gallate and penta-O-galloyl-glucoside that potential to possess scavenging activities towards hydroxyl radical, singlet oxygen and superoxide anion. From the pharmaceutical study, the gallate-type compounds (penta-O-galloyl-glucoside) exhibit distinct bioactivities such as antioxidant, anti-cardiovascular, anti-tumour and hepaprotective effects. The major antioxidant in mango peels is from polyphenols, carotenoids and anthocyanins (Jahurul, et al., 2015). Table 2.3 below shows the total phenolic compounds present in mango peels on a dry matter basis.

Table 2.3: Phenolic compounds in mango peels (mg/kg) on dry matter basis (Martin and He, 2009).

Compound	Amount
Mangiferin	1690.4
Isomangiferin	134.5
Mangiferin gallate	321.9
Isomangiferin gallate	82.0
Quercetin 3-0-galactoside	651.2
Quercetin 3-0-glucoside	557.7
Quercetin 3-0-xyloside	207.3
Quercetin 3-0-arabinopyranoside	101.5
Quercetin 3-0-arabinofuranoisde	103.6
Quercetin 3-0-rhamnoside	20.1
Kaempferol 3-0-glucoside	36.0
Rhamnetin 3-0 galactoside/glucoside	94.4
Quercetin	65.3
Total	4066.0

2.6.2 Drying Methods

Marçal and Pintado (2021) stated that mango peels are incredibly perishable because of their high level of moisture (62–83%), nutritional makeup, and microbial burden, which prevents the food industry from reusing them. Thus, by

drying the mango peels, microbial growth and enzyme activity can be reduced to slow down the deterioration process and ease storing and transport (Marçal and Pintado, 2021). Mango peels can be processed into powder by drying, which simplifies this by-product to be incorporated into a variety of food products. Nevertheless, the extreme temperature during the drying process can alter the chemical composition, sensory qualities and bioactive compounds of mango peels (Marçal and Pintado, 2021). The authors also claimed that phenolic compounds are more vulnerable to high temperatures such as flavonoids and xanthones while others maintain stable at 60˚C but it may decrease the phenolic amount by approximately 2.82 times as compared to fresh mango peels. The freeze-drying method is more appropriate to dry mango peels rather than oven-drying as this can mainly retain their phenolic content in the peels. According to Dorta, et al. (2012), oven-dried mango peels are shown to have lesser antioxidant activity, and this has proven the deterioration of phenolic compounds in mango peels at elevated temperatures due to enzymatic or chemical decomposition.

2.6.3 Mango Peels Incorporated into Different Products

In the study done by Ajila, et al. (2010), the authors incorporate mango peels into macaroni with different percentage levels (2.5%, 5.0% and 7.5%) and found that the polyphenols, carotenoid content and total dietary fibre were increased significantly while the macaroni becomes harden. They concluded that it is possible to integrate mango peel powder into macaroni to enhance its nutritional value

without deteriorating its texture and sensory qualities (cited in Jahurul, et al., 2015). Another study done by Ajila, Leelavathi, and Prasada Rao (2008) stated that antioxidant properties and dietary fibre were being enhanced when mango peel powder incorporated into soft dough biscuits (cited in Jahurul, et al., 2015).

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Materials

Fresh Thailand Mango Susu Gold (*Mangifera indica*) was obtained from Kedai Buah NANA, Kampar while gelatine and citric acid were purchased from the Double 8 ingredients supplies in Kampar, Perak, Malaysia. The monk fruit sweetener and date fruit sweetener were bought from MD Keto Home & Garden and Healthy Valley Online Store respectively which are online shops on the Shopee platform, Malaysia. The list of ingredients, instruments and chemicals used in this study are listed in Table 3.1, Table 3.2 and Table 3.3.

Table 3.1: List of ingredients used in this study.

Ingredients	**Category**	**Brand**	**Country produced**
Citric acid	Food preservative	-	Malaysia
Date fruit sweetener	Natural sweetener	MH Food	Malaysia
Gelatine	Gelling agent	-	Malaysia
Monk fruit sweetener	Natural sweetener	Lakanto	Malaysia
Ripened Mango	Fruit	Mango Susu Gold	Thailand

Table 3.2: List of instruments used in this study.

Instruments	Model	Brand	Country
Analytical balance	ML304T	Mettler Toledo	Ohio, US
Centrifuge machine	Mikro 22R	Hettich	Germany
Chiller (4˚C)	R-V420P3M	Hitachi	Japan
Colorimeter	CM-600d	Konica Minolta	Japan
Drying Oven	DIN 12880	Binder	Germany
Freeze Dryer	Cool Safe 110-4	Scanvac	Denmark
Freezer (-20˚C)	DW-FL270	Remi	-
Kitchen Blender	NL9206AD-4	Philips	China
Magnetic stirrer machine	SP131320-33	Thermo Scientific	China
Induction Cooker	FCC FORNELLO 2000	Faber	Malaysia
pH meter	FiveEasyPlus FP20	Mettler Toledo	Ohio, US

Table 3.2: List of instruments used in this study (continued).

Instruments	Model	Brand	Country
Pocket Refractometer	3830 PAL-3	ATAGO	Japan
Spectrophotometer	Genesys	Thermo Scientific	United States
Stainless steel blender	NBL-C501SS	Nippon	Japan
Texture analyzer	TA.XT Plus	Stable Micro Systems	United Kingdom
Water activity meter	LabSwift-aw	Novasina	Switzerland

Table 3.3: List of chemicals used in this study.

Chemical	Brand	Country
Aluminium chloride	Merck KGaA	Germany
Folin & Ciocalteu's Phenol reagent	Chemiz	-
Gallic acid	R&M Chemicals	United Kingdom
L-ascorbic acid	Himedia	India
Metaphosphoric acid	Synerlab	-
Methanol	Merck KGaA	Germany
Sodium bicarbonate	Chem Soln	-
Sodium carbonate	Himedia	India
Sodium hydroxide	Gene Chemicals	-
Sodium nitrate	R&M Chemicals	United Kingdom
Quercetin	Acros Organics	Spain
2,2-Diphenyl-1-picrythydrazyl (DPPH)	Chem Soln	-

Table 3.3: List of chemicals used in this study (continued).

Chemical	Brand	Country
2,6-dichlorophenol-indophenol (DCPIP) dye	Bendosen	Malaysia

3.2 Sample Preparation of Gummy Candy

3.2.1 Mango Peels

The mango peels were collected from fruit stalls in Kampar, Perak and washed with running water to eliminate the dirt. Next, the mango peels were soaked in 2 L of water with 28 g of baking soda for 15 mins to get rid of the pesticide in the peels. The mango peels were washed thoroughly in running water 3 times and air dried under the fan. The cleaned mango peels were put into the container, labelled and stored in the -20˚C freezer (DW-FL270, Remi) overnight before it further undergoes freeze drying. The mango peels were dried in the freeze dryer (Cool Safe 110-4, Scanvac, Denmark) for 36 h and fully dried mango peels were ground by using stainless steel blender (NBL-C501SS, Nippon, Japan) into fine powder form. The mango peel powder was stored in a glass container and put under -20˚C for future usage.

3.2.2 Mango Juice

The mango fruits were washed, cut into smaller pieces and blended with drinking water by using a kitchen blender (NL9206AD-4, Phillip, China). The ratio of mango juice to drinking water is 1:1.

3.3 Production of Gummy Candy

The slightly modified method of Romo-Zamarron, Perez-Cabrera and Tecante (2019) was performed for the gummy candy production. First, the gelatine was hydrated with the water, stirred, and left remaining for 30 mins. The sweetener and citric acid were added to the water at the temperature of 70˚C and continued to cook using an induction cooker (FCC FORNELLO 2000, Faber, Malaysia) until it reached the temperature of 105˚C. The concentrated sweetener syrup was then cold to the temperature of 60˚C and the hydrated gelatine was added to the concentrated sweetener syrup. The endpoint of the total soluble solid (˚Bx) was measured by a pocket refractometer (3830 PAL-3, ATAGO, Japan). Next, the mango peel powder and mango juice were added and mixed well. The gel was poured into the mould shape and kept at 4˚C for 24 h. The gummy candies produced were stored at a chiller (4˚C) (R-V420P3M, Hitachi, Japan) for further analysis. Table 3.4 below shows the formulation of making gummy candy with mango peels and different sweeteners.

Table 3.4: Formulation of control and gummy candy with different sweeteners.

Materials	Gummy candy with different sweeteners (%)	Remarks
Gelatine	4.5	-
Water	20.5	add with gelatine
	39.8	add with sweetener and citric acid
Sweetener	20	Table sugar: sucrose Monk fruit sweetener: monk fruit extract + erythritol Date fruit sweetener: original organic dried date powder
Citric acid	0.5	-
Mango juice	13.7	-
Mango peels	1	-
Total (%)	100	-

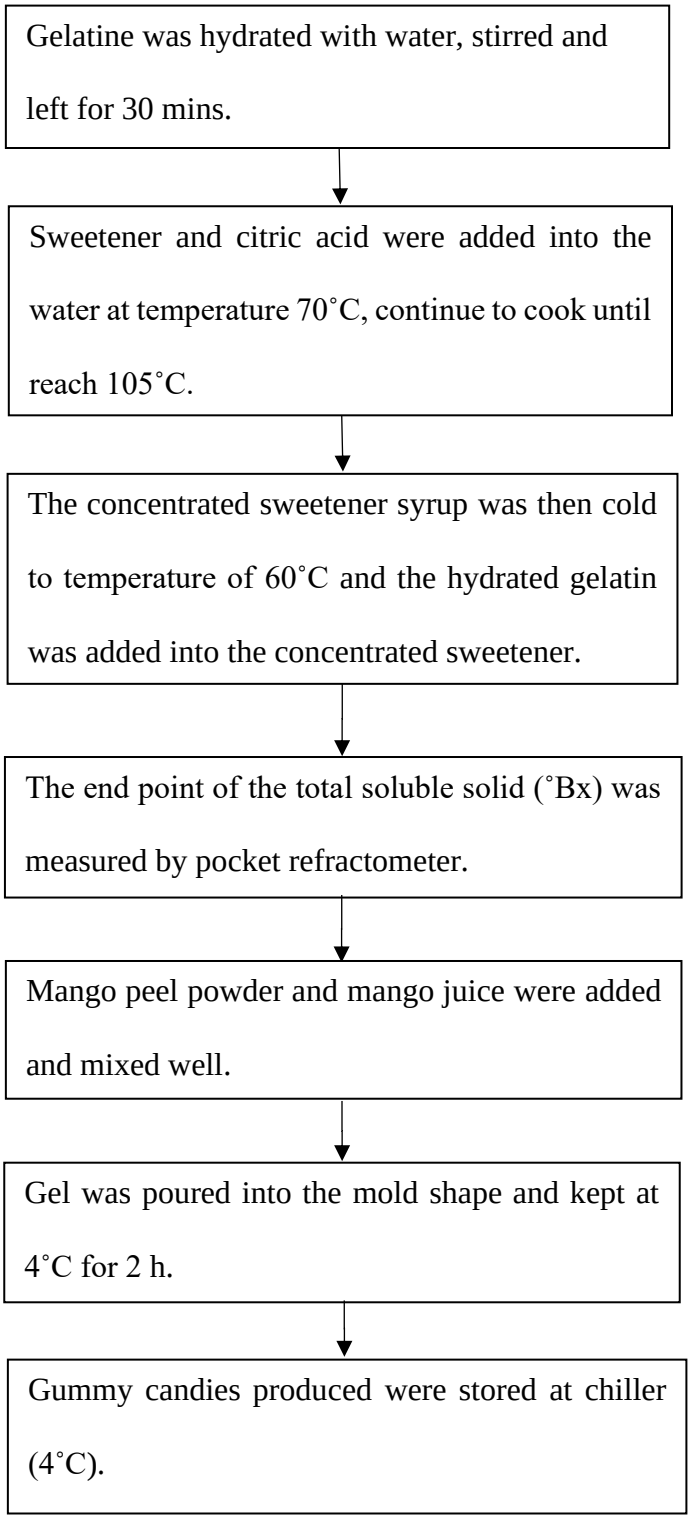

Figure 3.1: Flowchart of gummy candy production (Romo-Zamarron, Perez-Cabrera and Tecante, 2019).

3.4 Extraction

The extraction for gummy candy is performed according to Lee, et al. (2009) with slight modifications. First, the 0.5 g of samples were weighed and extracted at room temperature. The weighed samples were mixed with 5 mL of 80% of methanol and poured into a 50 mL beaker. The samples were stirred using a magnetic stirrer for 30 mins. The stirred samples were poured into the centrifuge tube and centrifuged at 4,000 rpm for 15 mins at 4˚C by a centrifuge machine (Mikro 22R, Hettich, Germany). The supernatants were transferred to another new centrifuge tubes and stored at -20˚C for further analysis.

3.5 Physicochemical Properties

3.5.1 Total Soluble Solid (TSS) Content

The total soluble solid content was measured by using a pocket refractometer (˚Brix) (3830 PAL-3, ATAGO, Japan) after adding the hydrated gelatine into the concentrated sweetener syrup. The measurements were carried out in triplicate with mean ± standard deviation for the samples.

3.5.2 Moisture Content

The moisture content was determined by the oven drying method according to the Association of Official Analytical Chemists (Helrich, 1990). First, the drying oven (DIN 12880, Binder, Germany) was heated to 105˚C and kept the temperature constant. Nine crucibles were cleaned and dried in the drying oven for 1 h. The crucibles were transferred into a desiccator by using a thong to let them cool for 1 h. Next, the crucibles were placed on an analytical balance (ML304T, Mettler Toledo, Ohio US) and weighed rapidly and accurately. About 5 g of samples were weighed and placed into the crucibles respectively. The crucibles containing samples were placed into the drying oven, maintained at 105˚C and left for 24 h. The crucibles were taken out from the oven by using a thong and placed into a desiccator for 1 h to cool down. The crucibles were weighed together with the dried samples to obtain a constant weight. All the measurements were carried out in triplicate with mean ± standard deviation for the samples.

3.5.3 Water Activity Content

The water activity (A_w) of gummy candies was measured by a water activity meter (LabSwift-aw, Novasina, Switzerland). The results were reported as the mean ± standard deviation of triplicate samples.

3.5.4 pH Content

The pH value of the gummy candies was determined by using a pH meter that was calibrated under different standard buffer solutions of pH 4.0, 7.0 and 9.0 respectively. First, 1 g of sample with 9 mL of distilled water was mixed thoroughly by using a magnetic stirrer at the temperature of 50˚C. Then the pH of the suspension was measured by a digital pH meter (FiveEasyPlus FP20, Mettler Toledo, Ohio US). Results of triplicate measurements were reported as mean ± standard deviation (Multu, Tontul and Erbas, 2018).

3.5.5 Colour Determination

The colour parameters (L^*, a^* and b^*) of the gummy candies were measured by a handheld Hunter colorimeter CIELAB system (CM-600d, Konica Minolta, Japan) and the parameters are obtained (L^* = lightness, a^* = greenness to redness and b^* = blueness to yellowness) under illuminant D65. The colorimeter was calibrated with zero and white calibration before the sample's evaluation. The measurement on gummy candies was taken at different points on the gummy candies' surface. The results were reported as the mean ± standard deviation of triplicate samples.

3.5.6 Texture Analysis

The texture profile analysis of gummy candies was measured by the texture analyser (TA.XT Plus, Stable Micro System, United Kingdom) with the cylinder

probe (35 mm). The texture properties (firmness) of gummy candies were measured. The analysis was conducted in the room temperature with the pre-test speed of 2 mm/s, test speed of 1 mm/s and the post-test speed of 1 mm/s, the distance between the probe and sample was 10 mm with the trigger force of 5 g and the time for the two compression was 2 s (Multu, Tontul and Erbas, 2018).

3.6 Phytochemical Properties

3.6.1 Total Phenolic Content

The total phenolic content of the samples was measured based on Folin-Ciocalteu method with slight modifications from Khaw, Hasnah and Chan (2016). The reference solution (standard) for this assay was gallic acid (GA). A 10 mg/mL of gallic acid standard solution was prepared by dissolving 0.1 g of gallic acid in 10 mL of 99.9% methanol to get 1% of the standard solution. Then, a calibration curve was constructed by further diluting the stock solution into several standard solutions with concentrations of 0.02, 0.06, 0.2, 0.6, and 1.0 mg/mL with methanol and the preparation of these standard solutions is shown in Appendix A. The stock solutions were wrapped in aluminium foil during preparation as they were indeed light sensitive. Then, 0.1 mL of each dilution was mixed with 0.5 mL of distilled water, followed by 0.1 mL of Folin reagent and allowed to incubate for 5 mins. After the incubation, 1 mL of 7% sodium carbonate (Na_2CO_3) was poured into the mixture and stood for 100 mins at room temperature for colour development. The

same approaches were used for the determination of the total phenolic content of gummy candies. The mixture was sent for the vortex to ensure they were mixed thoroughly after each mixing step. The absorbance was measured at 765 nm by using a spectrophotometer (Genesys, Thermo Scientific, United States). An 80% methanol was served as the blank. The total phenolic content is expressed in the µg of gallic acid equivalent (GAE)/mL of the dry weight, with the mean ± standard deviation of triplicate samples (Khaw, Hasnah and Chan, 2016).

3.6.2 Total Flavonoid Content

The flavonoid content of the samples was measured based on the aluminium chloride complex-forming assay described by Khaw, Hasnah and Chan (2016) and Senguttuvan, Paulsamy and Karthika (2014) with slight modifications. Quercetin (QE) was used as the standard solution for this assay. A 10 mg/mL of quercetin standard solution was prepared by dissolving a 0.1 g quercetin in 10 mL 99.9% methanol to get a 1% standard solution. The dilutions of 0.02, 0.06, 0.2, 0.6, and 1.0 mg/mL concentrations of quercetin standard solution were prepared by using methanol and the preparation of these standard solutions is shown in Appendix B. The stock solutions were wrapped in aluminium foil during preparation as they were indeed light sensitive. Next, an aliquot of 0.15 mL from each stock dilution was mixed with 0.5 mL of distilled water in a centrifuge tube followed by 0.15 mL of 5% sodium nitrite ($NaNO_3$) solution was added and incubated at 25˚C for 5 mins. After the incubation, a 0.15 mL 10% aluminium chloride ($AlCl_3$) solution was

added and incubated again for another 5 mins. Then, 2 mL of 4% sodium hydroxide (NaOH) was added and incubated at 25˚C for 10 mins. The same approaches were used for the determination of the total flavonoid content of gummy candies. The mixture was sent for the vortex to ensure they were mixed thoroughly after each mixing step. Specifically, the appearance of the pink solution indicates the presence of flavonoid content. The absorbance was read at 510 nm by using a spectrophotometer (Genesys, Thermo Scientific, United States). An 80% methanol was served as the blank. The total flavonoid is expressed as the µg of quercetin equivalent (QE)/mL of dry weight. The determinations were analysed in triplicate with mean ± standard deviation (Khaw, Hasnah and Chan, 2016; Senguttuvan, Paulsamy and Karthika, 2014).

3.6.3 Ascorbic Acid Content

Ascorbic acid (Vitamin C) content of gummy candies was determined by using the 2,6 dichlorophenol-indophenol (DCPIP) dye titration method by Association of Official Analytical Chemists (Helrich, 1990). A solution containing 3% metaphosphoric acid (HPO_3) was prepared by dissolving the 30.0 g of metaphosphoric acid in 1000 mL of distilled water. The DCPIP dye solution was prepared by dissolving 50 mg of DCPIP in 150 mL of hot water containing 42 mg of sodium bicarbonate. The samples were prepared by using 10 g of gummy candy blended with 9 mL of 3% HPO_3 solution and filtered and poured into a 100 mL volumetric flask. The volume was made up to 100 mL using 3% HPO_3. An aliquot

(10 mL) of the sample was taken for titration against 2,6 dichlorophenol-indophenol dyes until a pink colour persisted for 15 s.

A standard ascorbic acid solution was prepared by dissolving the 100 mg of L-ascorbic acid in 100 mL of 3% metaphosphoric acid (HPO_3) solution. An aliquot (1 ml) of the standard was pipetted out and a further 9 ml of 3% metaphosphoric acid (HPO_3) solution was added to the 1 ml of the standard to create a standard solution with the concentration of 1 mL = 0.1 mg ascorbic acid.

An aliquot (5 mL) of the standard solution was added and mixed with 5 mL of HPO_3 and the solution was titrated with the DCPIP until the appearance of the persistent faint pink colour for 15 s. The dye factor was determined by using the formula below. The dye factors were calculated by titrating the standard ascorbic acid against 2,6 dichlorophenol-indophenol. The ascorbic acid will be calculated by using the following formula:

Dye factor = 0.5/Titre value (mL)

Ascorbic Acid (mg $100g^{-1}$) =

$$\frac{\text{Dye factor} \times \text{Titre value (mL)} \times \text{Volume made up (100 mL)} \times 100}{\text{Sample weight (10 g)} \times \text{Aliquot taken for estimation (10 mL)}}$$

3.7 Antioxidant Properties

3.7.1 DPPH Radical Scavenging Activity

The DPPH radical scavenging activity for the antioxidant assay was described by Chai and Wong (2012) with slight modifications. First, 0.5 mL of sample was added to 0.7 mL of DPPH (0.10 mM in methanol) and incubated under the dark at room temperature for 30 mins. The mixture was vortex before incubation to ensure the sample was fully mixed well. After the incubation time, the absorbance was read at 517 nm by using a spectrophotometer (Genesys, Thermo Scientific, United States). An 80% methanol was served as the blank. DPPH radical scavenging activity (%) was calculated by using the following formula:

$$\text{DPPH radical scavenging activity (\%)}$$

$$= \{1- (A_{sample}/A_{blank})\} \times 100$$

where A_{Blank} is the absorbance of blank control reaction which without sample and A_{Sample} is the absorbance of the sample.

3.8 Sensory Properties

The sensory evaluation of the gummy candies was conducted by using acceptance test 9-point hedonic scale (1 = dislike mostly; 9 = like mostly) for total 50 untrained panellists in UTAR, Kampar campus. The samples were presented in random ordered and labelled with randomly generated three-digit codes (Charoen, 2015;

Romo-Zamarron, Perez-Cabrera and Tecante, 2019). The sensory attributes were determined in terms of appearance, aroma, taste (sweetness), texture (chewiness) and the overall acceptability of the gummy candies. The questionnaires for 9-point hedonic scale were prepared for panellists to evaluate the samples shown in Appendix C.

3.9 Statistical Analysis

The data of physicochemical, phytochemical and sensorial properties of gummy candies produced by different types of sweeteners in the formulation are expressed as mean ± standard deviation (n = 3). The variables of this research were types of sweeteners used while control represented table sugar, T1 and T2 represented monk fruit sweetener and date fruit sweetener, respectively. One-way analysis of variance (ANOVA) and Tukey's analysis were used to determine the significant difference ($p < 0.05$) for the mean in the physicochemical, phytochemical and sensorial analysis. The data was analysed by the IBM SPSS Statistics software (version 28.0.1.1) with the aid of Microsoft Excel for Microsoft 365 MSO (Version 2204 Build 16.0.15128.20278).

CHAPTER 4

RESULTS

4.1 Physicochemical Properties

4.1.1 Total Soluble Solid (TSS) Content

Figure 4.1 shows the average value of total soluble solid content obtained from control, monk and date fruit gummy candies. The control perceived the highest ˚Brix value which was 58.60˚Brix with a standard deviation of 0.44 and a temperature of 43.7˚C while T1 and T2 showed 45.3˚Brix (±0.30) with a temperature of 44.1˚C and 38.33˚Brix (±0.42) with temperature 44.2˚C, respectively. This showed a significant difference ($p < 0.05$) between three gummy candies in the ANOVA and Tukey's test.

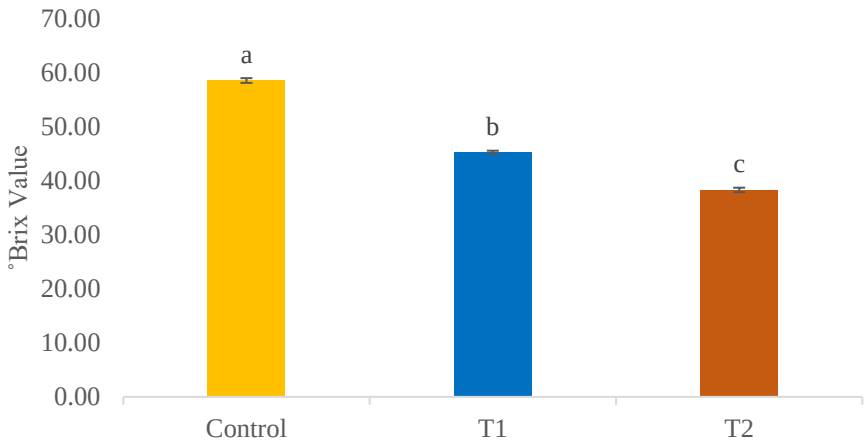

Figure 4.1: ˚Brix value of three gummy candies with different sweeteners. Means ± standard deviation (n = 3) with different superscript letters (a-c) indicates the significant differences ($p < 0.05$). Control = table sugar sweetener; T1 = Monk fruit sweetener; T2 = Date fruit sweetener.

4.1.2 Moisture Content

Based on Figure 4.2, the moisture content of T2 was significantly higher ($p < 0.05$) than the control and T1, while the control and T1 did not show any significant difference ($p > 0.05$). Figure 4.2 illustrates the percentage of moisture content among gummy candies with the highest percentage in T2 (60.42%) followed by control (54.42%) and T1 (53.09%) respectively. The standard deviation for T2, control and T1 were 4.21, 2.20 and 1.67 accordingly.

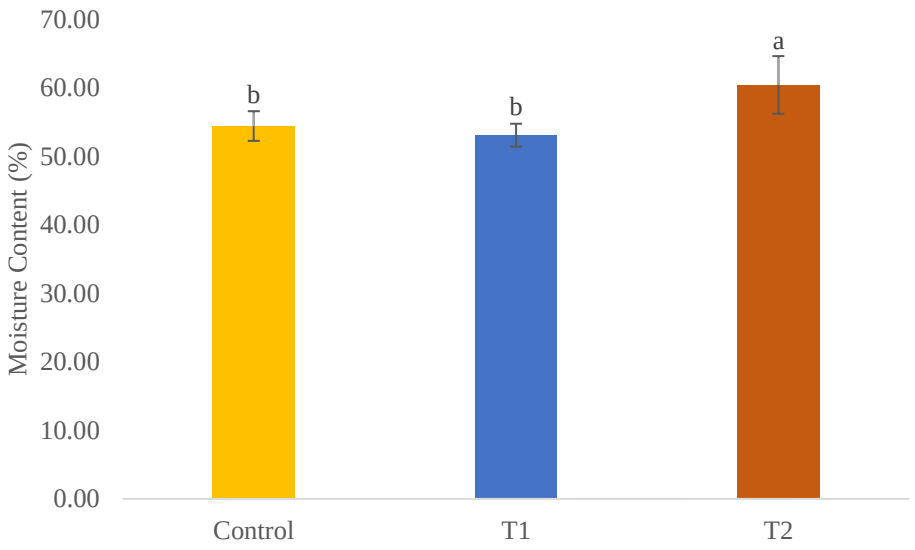

Figure 4.2: The percentage of moisture content of three gummy candies with different sweeteners. Means ± standard deviation (n = 3) with different superscript letters (a-b) indicates the significant differences ($p < 0.05$). Control = table sugar sweetener; T1 = Monk fruit sweetener; T2 = Date fruit sweetener.

4.1.3 Water Activity Content

Figure 4.3 shows the mean water activity of triplicate results among the three gummy candies. Based on the result, there was a significant difference ($p < 0.05$) among all the samples while T1 perceived the highest water activity (0.68). The average water activity for control, T1 and T2 were 0.58, 0.68 and 0.63 with the standard deviation of 0.03, 0.01, and 0.01 respectively.

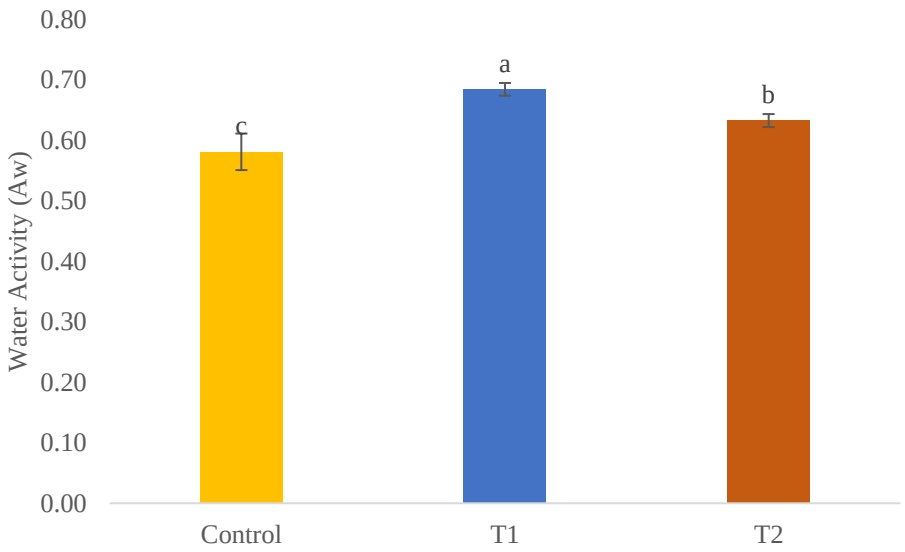

Figure 4.3: Water activity of three gummy candies with different sweeteners. Means ± standard deviation (n = 3) with different superscript letters (a-c) indicates the significant differences ($p < 0.05$). Control = table sugar sweetener; T1 = Monk fruit sweetener; T2 = Date fruit sweetener.

4.1.4 pH Content

As shown in Figure 4.4, T2 was significantly higher ($p < 0.05$) than the control and T1 while the control and T1 did not show a significant difference ($p > 0.05$) in the pH value. The control was reported to have a pH value of 3.74, while the T1 and T2 have pH values of 3.82 and 4.14 respectively.

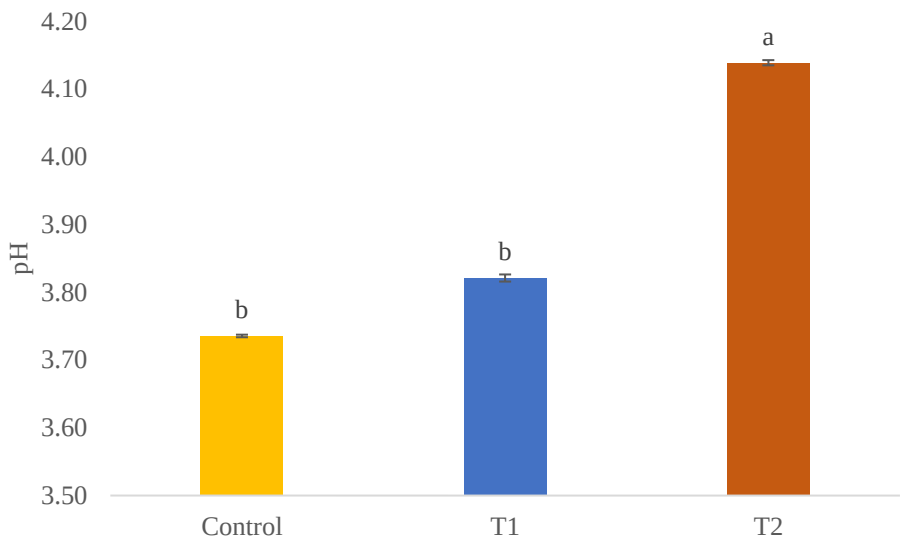

Figure 4.4: pH value of three gummy candies with different sweeteners. Means ± standard deviation (n = 3) with different superscript letters (a-b) indicates the significant differences ($p < 0.05$). Control = table sugar sweetener; T1 = Monk fruit sweetener; T2 = Date fruit sweetener.

4.1.5 Colour Determination

The colour determination of the CIELAB system includes the colour parameters such as lightness (L^*), redness (a^*) and yellowness (b^*) of gummy candies were tabulated in Table 4.1. A significant difference ($p < 0.05$) was observed in the lightness (L^*) and redness (a^*) among three gummy candies while the yellowness (b^*) did not exhibit a significant difference ($p > 0.05$) in three gummy candies. The T1 perceived the highest lightness value (67.42) followed by control (39.59) and T2 (35.35) respectively. T1 showed the lowest redness value (1.92) compared to control (5.47) and T2 (10.10) thus this gives a significant difference between the three gummy candies. For the yellowness (b^*), three gummy candies perceived a similar value from control (22.35), T1 (20.03) and T2 (18.37) respectively. Figure

4.5 shows the final products of three gummy candies made from table sugar (control), monk fruit sweetener (T1) and date fruit sweetener (T2) viewed from left to right.

Table 4.1: Colour parameters such as lightness (*L**), redness (*a**) and yellowness (*b**) of the gummy candies produced from different sweeteners.

Samples	**D65**		
	L*	***a****	***b****
Control	39.59 ± 2.92^{b}	5.47 ± 1.2^{b}	22.35 ± 1.76^{a}
T1	67.42 ± 1.38^{a}	1.92 ± 0.70^{c}	20.03 ± 2.20^{a}
T2	35.35 ± 1.26^{c}	10.10 ± 0.70^{a}	18.37 ± 1.23^{a}

Means ± standard deviation (n = 3) with different superscript letters (a-c) indicates the significant differences ($p < 0.05$).

Control = table sugar sweetener; T1 = Monk fruit sweetener; T2 = Date fruit sweetener.

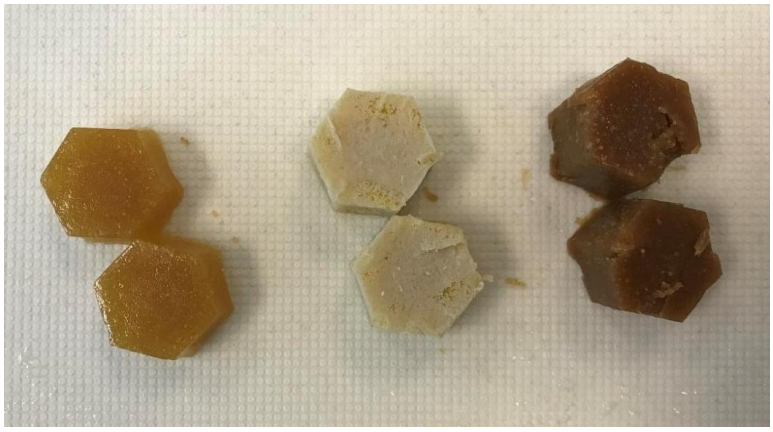

Figure 4.5: The final products of gummy candies made from table sugar (control), monk fruit sweetener (T1) and date fruit sweetener (T2) viewed from left to right.

4.1.6 Texture Analysis

Figure 4.6 shows the firmness (N) parameter of the texture analysis of three gummy candies with a significant difference ($p < 0.05$) between the control and T1 and T2, while T1 and T2 did not show a significant difference ($p > 0.05$) in the firmness of gummy candies. The control perceived the firmest texture (80.82 N) compared to T1 (32.12 N) and T2 (34.89 N) gummy candies.

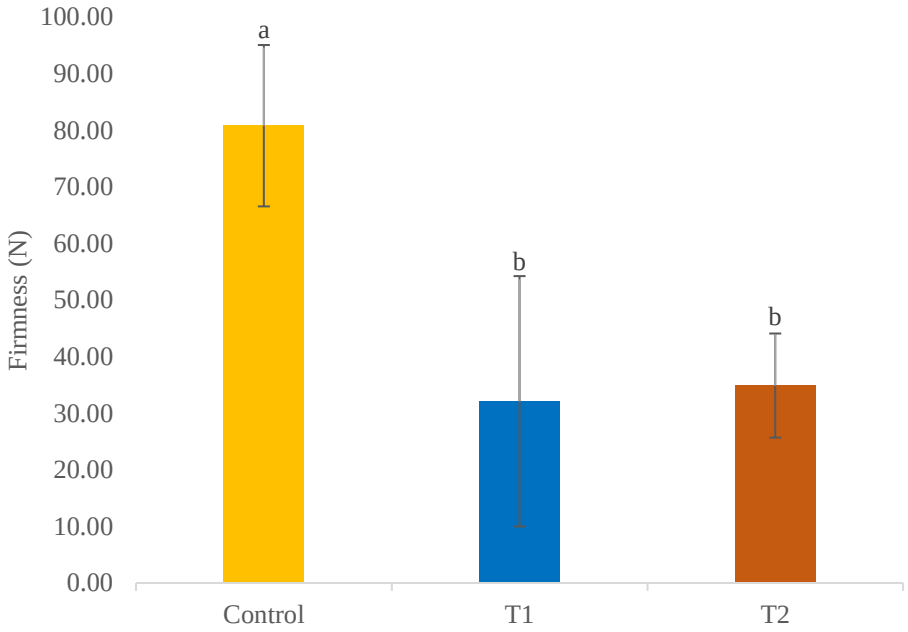

Figure 4.6: The firmness (N) of three gummy candies with different sweeteners. Means ± standard deviation (n = 3) with different superscript letters (a-b) indicates the significant differences ($p < 0.05$). Control = table sugar sweetener; T1 = Monk fruit sweetener; T2 = Date fruit sweetener.

4.2 Phytochemical Properties

4.2.1 Total Phenolic Content

The total phenolic content (µg GAE/ml) of three gummy candies was illustrated in Figure 4.7 while the standard curve for gallic acid with the R^2 value of 0.9992 as well as the concentration and absorbance of standard gallic acid were plotted in Appendix A. The total phenolic content of gummy candies was varied and T2 perceived the highest total phenolic content with 69.00 µg GAE/ml of GAE followed by T1 (41.00 µg GAE/ml) and control (39.00 µg GAE/ml) respectively. The control and T1 have a significant difference ($p < 0.05$) against T2 when carrying out ANOVA test.

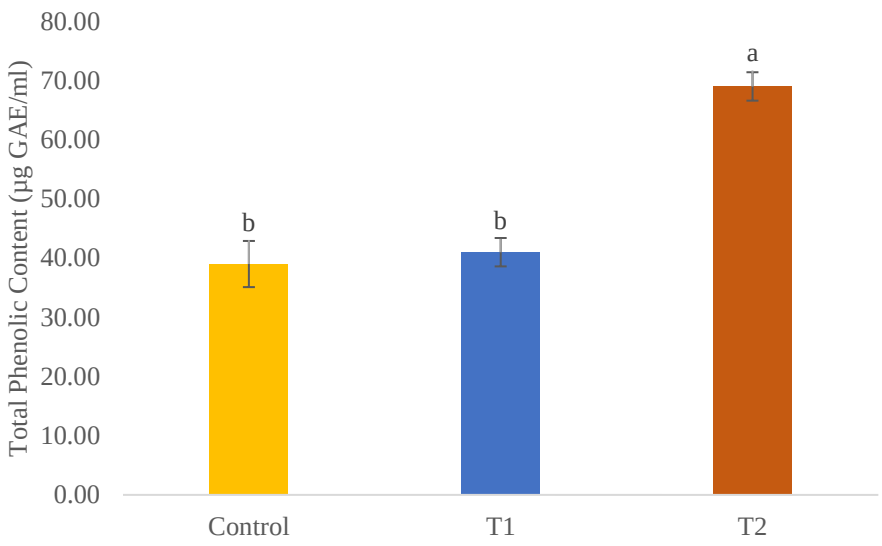

Figure 4.7: Total phenolic content (µg GAE/ml) of three gummy candies with different sweeteners. Means ± standard deviation (n = 3) with different superscript letters (a-b) indicates the significant differences ($p < 0.05$). Control = table sugar sweetener; T1 = Monk fruit sweetener; T2 = Date fruit sweetener.

4.2.2 Total Flavonoid Content

Figure 4.8 shows the total flavonoid content (µg QE/ml) in three gummy candies. The standard curve for quercetin was shown in Appendix B with the R^2 value of 0.9985 as well as the concentration and absorbance of standard quercetin. There was a significant difference ($p < 0.05$) between control and T1 while no significant difference ($p > 0.05$) was observed between control and T2 as well as T1 and T2. T1 perceived the highest total flavonoid content which was 680.00 µg QE/ml while T2 and control were recorded to have 550.00 µg QE/ml and 359.00 µg QE/ml flavonoid content respectively.

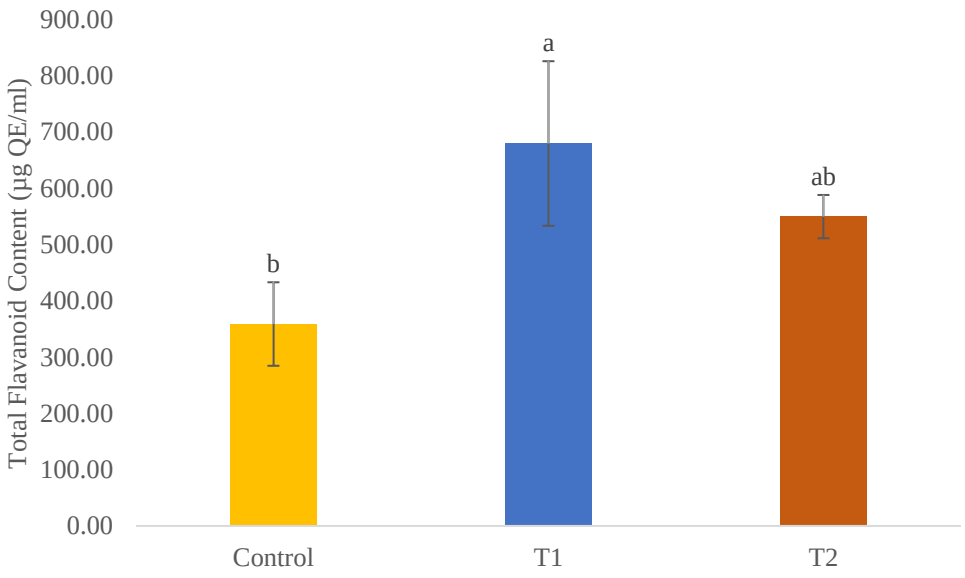

Figure 4.8: Total flavonoid content (µg QE/ml) of three gummy candies with different sweeteners. Means ± standard deviation (n = 3) with different superscript letters (a-b) indicates the significant differences ($p < 0.05$). Control = table sugar sweetener; T1 = Monk fruit sweetener; T2 = Date fruit sweetener.

4.2.3 Ascorbic Acid Content

Table 4.2 shows the average ascorbic acid content (mg/100 g) of three gummy samples. Based on the result, there were no significant differences ($p > 0.05$) among the three gummy candies as they were recorded with 50 mg/100g ascorbic acid content present in the gummy samples. The ascorbic acid content was calculated based on the formula stated in Section 3.6.3.

Table 4.2: Ascorbic acid content (mg/100 g) of three gummy candies with different sweeteners.

Samples	Ascorbic acid content (mg/100 g)
Control	50.00 ± 0.00^{a}
T1	50.00 ± 0.00^{a}
T2	50.00 ± 0.00^{a}

Means ± standard deviation (n = 3) with different superscript letters (a) indicates the significant differences ($p < 0.05$).

Control = table sugar sweetener; T1 = Monk fruit sweetener; T2 = Date fruit sweetener.

4.3 Antioxidant Properties

4.3.1 DPPH Radical Scavenging Activity

The percentage of DPPH radical scavenging activity among three gummy candies was plotted in Figure 4.9. There was a significant difference ($p < 0.05$) in T2 among others while T1 and control did not perceive a significant difference ($p > 0.05$). The determinants of DPPH radical were expressed in percentages which T2 having the highest percentage (85.15%) of DPPH radical scavenging activity, followed by T1 (61.47%) and control (60.94%) respectively.

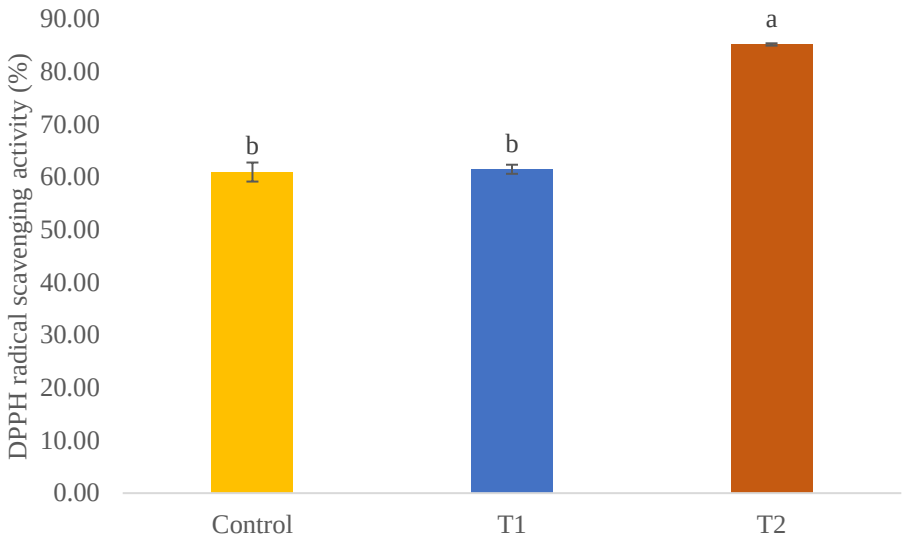

Figure 4.9: The DPPH radical scavenging activity (%) of three gummy candies with different sweeteners. Means ± standard deviation (n = 3) with different superscript letters (a-b) indicates the significant differences ($p < 0.05$). Control = table sugar sweetener; T1 = Monk fruit sweetener; T2 = Date fruit sweetener.

4.4 Sensory Properties

Based on Table 4.3 with the mean score of all sensory attributes for three gummy candies by using a 9-point hedonic scale, the control perceived the highest score among the other candies in all sensory attributes with appearance (6.88), aroma (6.48), taste (6.86), texture (6.82) and overall acceptability (7.18) while the T2 gummy candy has the lowest score among the candies. The analysis of variance (ANOVA) showed that control, T1 and T2 were significantly different ($p < 0.05$) in appearance and overall acceptability while control and T1 were not significantly different ($p > 0.05$) in aroma, taste and texture attributes. This shows that control and T1 have similar scores in the sensory attributes (aroma, taste and texture). On

the other hand, a significant difference ($p < 0.05$) was shown in T2 with other gummy candies, and it perceived the lowest score in the hedonic scaling.

Table 4.3: Mean score of sensory attributes for control, T1 and T2 by using 9-point hedonic scale.

Samples	Appearance	Aroma	Taste	Texture	Overall acceptability
Control	6.88 ± 1.33^{a}	6.48 ± 1.581^{a}	6.86 ± 1.25^{a}	6.82 ± 1.24^{a}	7.18 ± 0.94^{a}
T1	5.86 ± 1.67^{b}	6.12 ± 1.380^{a}	6.46 ± 1.39^{a}	6.30 ± 1.69^{a}	6.54 ± 1.18^{b}
T2	4.20 ± 1.76^{c}	5.18 ± 1.548^{b}	4.70 ± 1.70^{b}	3.66 ± 1.80^{b}	4.02 ± 1.65^{c}

Means ± standard deviation (n = 3) with different superscript letters (a-c) indicates the significant differences ($p < 0.05$).

Control = table sugar sweetener; T1 = Monk fruit sweetener; T2 = Date fruit sweetener.

CHAPTER 5

DISCUSSION

5.1 Physicochemical Properties

5.1.1 Total Soluble Solid (TSS) Content

The total soluble solid (TSS) content of the control, T1 and T2 were found to be in the range of 38–58˚Brix ($p < 0.05$) which is lower than the normal degree Brix of the commercial gummy candies (74–80˚Brix) (Ge, et al., 2020). According to Lees and Jackson (1992), total soluble solid content is the components that dissolved in water, and this typically refers to the sweetener that is present in the gummy candies. The significant difference ($p < 0.05$) shown in three gummy candies indicated that different sweetener substitutions can result in different total soluble solids content. The control has the highest value of ˚Brix value which is 58.60˚Brix but it is lower than the commercial gummy candies mainly due to the absence of glycose syrup in the gummy candy formulation. According to Ge, et al. (2020), most gummy candy products are made from glycose syrup, sucrose, gelatine and water while sucrose and glucose syrup are the main ingredients that provide sweetness to the gummy candies. When there was only the presence of sucrose in the control, this shows that

the total concentration of sugar was decreased compared to commercial gummy candies.

T1 perceived 45.3˚Brix with 6.97˚Brix higher than T2 might be due to the presence of 80% mogrosides from the monk fruit sweetener but still need to depend on the percentage range of mogroside V from 25–30% in the refined monk fruit extract (Hadjikinova, 2022). Due to its high level of sweetness (> 300 times that of sucrose) and lower calorific value than sucrose, the mogroside extract from ripe monk fruit may be the perfect alternative to sugar for diabetic and obese patients (Pandey and Chauhan, 2019). Jane (2019) stated that due to the highly intense sweetening effect from the mogrosides, the monk fruit sweeteners were usually mixed with erythritol to decrease the intensity of the aftertaste in the monk fruit sweetener. As stated by Hadjikinova (2022), monk fruit sweetener has a lower bitter taste as compared to high-intensity sweeteners such as saccharin and acesulfame K as the presence of erythritol decreases its aftertaste. Regnat, et al. (2018) further explained that erythritol, with its scientific name ((2R,3S)-Butan-1,2,3,4-tetrol) is from polyols formed from the hydrolysation process of ketone or aldehyde group. The main function of erythritol present in monk fruit sweetener can act as a synergic effect that increases the mouthfeel of the sweetener while masking the undesirable bitter aftertaste in monk fruit sweetener (Regnat, et al., 2018).

T2 has the lowest ˚Brix value which is 38.33˚Brix compared to the other samples mainly due to the presence of glucose and fructose in the date's sweetener. The lowest percentage of sugar presence in date fruit sweetener (44–48%) is one of the reasons that caused low total soluble solid yield while the presence of pitted date in the ground date fruit sweetener with a higher amount of fibre decreases its solubility in water, and thus lower the total soluble solid of T2 sample (Splawn, 2019).

5.1.2 Moisture Content

Water present in gummy candies has an impact on the stability, textural qualities, shelf life, and microbial growth of food products (Efe, 2018). A reduced moisture level results in harder gummy candies that normally have a longer shelf life (Ergun, Lietha and Hartel, 2010). In this study, the oven drying method was used to determine the moisture content of gummy candies. Based on Figure 4.2, the moisture content in T2 was significantly different ($p < 0.05$) from T1 and control with the highest percentage which is 60.42%. Based on the study done by Rumali (2021), the author also found that the gelatine-based jelly candy that incorporated pineapple core as fruit waste was higher than average values among candies which were 44.70% while the study done by Renaldi, et al. (2022) stated that the gummy jelly incorporated with *Garcinia atroviridis* has the range of 33.16 to 42.01% of moisture content that is higher than average gummy products. However, according to Efe (2018) and Renaldi, et al. (2022), the typical gummy candies consist of 8 to 22% or less than 20% moisture content. Additionally, the gummy candies' final

moisture has a considerable impact on their quality, texture, and most significantly, their shelf life (Ge, et al., 2021).

The higher moisture content in gummy candy samples (T1, T2 and control) compared to commercial gummy candy in this study might be due to the different manufacturing processes between the gummy candy factories. According to Chaven (2014) and Ergun, Lietha and Hartel (2010), the hot liquid candy was poured into Mogul starch bed depositing machine and mould in dried corn starch and allowed to cool set in the commercial gummy candies production. The candy shapes were formed in the Mogul while the starch drew moisture from the candy piece and gives the jellies' surface a "skin-like" texture and this can aid in preventing distortion of the candies when they are taken out from the starch (Chaven, 2014; Ergun, Lietha and Hartel, 2010). Delgado and Bañón (2014) also stated that starch moulding can promote the drying rate and extraction from mould. The gummy candies might undergo drying process with the time varying from 24 to 72 hours depending on the final desired moisture content. Controlling drying speed is necessary as the surface may become excessively hard and trap moisture if skin development happens too quickly. As a result, the gummy candy's surface may start to "sweat" while being stored (Ergun, Lietha and Hartel, 2010). Delgado and Bañón (2014) further explained that the shorter time required to carry out the drying process, the better it is as drying requires a lot of resources. Most food companies are engaged in streamlining procedures to increase output while using the least amount of energy possible. However, the authors claimed that extending

the drying process is a typical industrial procedure to avoid textural issues in gummy candies (Delgado and Bañón, 2014).

The higher moisture content in three gummy candies might also be due to the low interaction to form a matrix between the polymer-rich phases and sugar's structure and this caused the bigger water molecules present in sugar especially date fruit sweetener used in the T2 sample bounded and entrapped in the gel matrix and lead to higher moisture content (Efe, 2018; Ergun, Lietha and Hartel, 2010). While control and T1 gummy candies have no significant difference ($p > 0.05$) from each other, this indicates that a further drying process needs to be carried out to decrease the moisture content in gummy candies.

Furthermore, the gummy candies made in this study only used the different types of sweeteners without using corn syrup which is one of the main ingredients used in gummy candies production. According to White (2009), corn syrup has the properties of absorbing moisture when increasing dextrose equivalent (DE) and the absence of corn syrup has an impact on the increasing of moisture content in gummy candies (control, T1 and T2). Ergun, Lietha and Hartel (2010) stated that the presence of water (20–35%) in gummy candies production can improve the dissolution of sugar and corn syrup but approximately 40% of water was used in this study to dissolve sugar into the sugar syrup and this caused excessive water amount in the gummy candy making, leading to the high moisture content of

gummy candies. The optimised formulation of the percentage in water is mainly due to the difficulty of dissolving date fruit sweetener as it contains fibre leaves tiny grit from the original pitted dates and thus, roughly 40% of water is being used to fully dissolve the sweetener to form sugar syrup (Splawn, 2019). Ergun, Lietha and Hartel (2010) further suggested that by using pressure dissolvers, it is possible to retain the moisture at elevated temperatures and even less water was used in production to dissolve sugar for rapid evaporation.

5.1.3 Water Activity Content

The water activity present was defined as the vapour pressure in gummy candies to the vapour pressure of the distilled water under the same temperature (FDA, 2018). Ergun, Lietha and Hartel (2010) stated water activity is a colligative quality based on the quantity and molecules' size in water, primarily impacted by the presence of dissolved sugars, additional sweeteners (polyols), salts (caramel), and humectants in confections. Based on Figure 4.3, three gummy candies have similar water activity values which are between 0.58 to 0.68 which is within the range of commercial gummy candies (0.50 to 0.75) (Ergun, Lietha and Hartel, 2010). The gummy candies in the study are significant differences with each other ($p < 0.05$). The study done by Samakradhamrongthai and Jannu (2021) showed that velvet tamarind chewy candy has water activity in the range of 0.70 to 0.96 which are higher than the water activity of gummy candies in this study. The authors further explained the higher percentage used of humectants such as xylitol and corn syrup

greatly affect the absorption of water towards the gummy candies. Another study done by Gok, et al. (2020) stated the water activity for mannitol and soluble wheat fibre gummy candies are quite high (0.76 to 0.84) compared to gummy candies in this study. Delgado and Bañón (2015) stated that gummy candy has a low water activity and is a moisture intermediate food that is rich in sugars and other hygroscopic ingredients, hence this makes them harder to dry. High temperature and relative humidity are needed to accelerate the dehydration rate, suspend the gel formation and increase the chances of surface crusting. Humectants present in gummy candy can retain the moisture of the products and decrease the water activity of the gummy candies. As described by Ergun, et al. (2010), humectants possess hydroxyl groups that tend to form hydrogen bonds with water molecules. Thus, the humectants present in gummy candies are sucrose, glucose and fructose which can decrease the water activity of gummy candies.

Samakradhamrongthai and Jannu (2021) claimed that the higher water activity in gummy candies indicated crystallisation that was caused by sugar alcohol or polyols, while the T1 sample underwent crystallisation caused by erythritol in monk fruit sweetener and thus it perceived the highest water activity content compared to other gummy candies. The crystal lattice is formed through an exclusionary process in T1 with the rapid rate of polyols crystallisation, which has an impact on the liquid phase's concentration of dissolved solids (Samakradhamrongthai and Jannu, 2021). The presence of polyols in monk fruit sweeteners (T1 sample) can retain the chewy texture over time when the water activity increased.

Control has the lowest water activity value (0.58) compared to others might be due to the lower molecular weight of sucrose in the control sample as well as the presence of sucrose that can lower the water activity of gummy candy. As control is made up of sucrose (sugar) in 20% of sugar in gummy candy formulation, the humectant can function well to decrease the water activity in control. Gok, et al. (2020) also stated that the presence of sucrose can bind more water, reduce free-water availability and hinder crystallisation in the control gummy candy. The T2 sample has a 0.63 water activity value is slightly higher than the control and this might be due to the components of the date fruit sweetener used in the T2 sample. The date fruit that only has 44–48% of sugar amount based on Table 2.2 has proven that a lower amount of humectant (glucose and fructose) is present in sweetener and decreases the water-binding capacity in the T2 sample.

5.1.4 pH Content

The pH of confectionery products is important because adding acid to fruit-flavoured products can enhance fruity flavours. Acid is essential when hydrocolloids were used to strengthen the stability of low-pH products. A hydrocolloid probably leaves the solution if it is maintained at its isoelectric point, where there are no nett charges (Edwards, 2000).

Based on Figure 4.4, the pH of three gummy candies was within the range of gummy candy products which was pH of 3.0 to 4.5 while the T2 sample was

perceived as significantly different ($p < 0.05$) compared to control and T1 which did not show a significant difference ($p > 0.05$) in both samples. From the research done by Romo-Zamarrón, et al. (2019), the pH of pineapple gummy candy was 3.53 while papaya gummy candy posed a pH of 3.85 which had a similar pH value to control and T1 samples. Another study done by Renaldi, et al. (2022) also stated that the gummy candies produced from *Garcinia atroviridis* had a pH value ranging from 3.35 to 3.46. Citric acid is one of the ingredients used in the typical production of gummy candies and this is the main reason that caused the acidity of gummy candies in the study. According to Søltoft-Jensen and Hansen (2005), citric acid is a tricarboxylic acid that serves antibacterial effects owing to its acidulation and indirect antioxidant by chelating metallic ions that catalyse oxidation. The chelating effect of citric acid can function as a preservative to prevent microbial growth (Søltoft-Jensen and Hansen, 2005). Other than that, the pH of gummy candy might also be influenced by the presence of mango peels in this study. According to Sreedharamurthy, Bathal and Obulam (2015), mango peels have a pH of 3.9 was incorporated into the gummy candies in this study and might decrease the pH value of the gummy candies.

On the other hand, the T2 sample perceived the highest pH value (4.14) compared to other samples might be due to the higher amount of dissociated acid in the gummy candy sample (Søltoft-Jensen and Hansen, 2005) The dissolution of date fruit sweetener in T2 sample is low and this might cause citric acid that added

during the production difficult to be dissolved in sweetener syrup during the production of gummy candy in Figure 3.1.

5.1.5 Colour Determination

The final product's acceptability by consumers is significantly influenced by colour (Kurt, Bursa and Toker, 2021). The gummy candies were made from natural ingredients without any addition of artificial colouring agents. The highest lightness (L^*) in the T1 sample is due to the presence of white colour of the appearance of T1 gummy candy. As stated in Section 4.1, monk fruit sweetener consists of both monk fruit extract and erythritol while the white colour present in the T1 is due to the crystallisation of erythritol, and thus this can increase the lightness of the T1 gummy candy sample (Morrill, 2021). According to Tyapkova, Bader-Mittermaier and Schweeiggert-Weisz (2012), erythritol crystallisation occurred in two major events which are nucleation and crystal growth. In the nucleation, the molecules that have been scattered throughout the solution begin to cluster together. A stable nucleus to support the crystal growth is formed when the clusters have reached the maximum size. Supersaturation drives the crystallisation process can be explained by the addition of solute molecules to the initial nuclei during the crystal formation process, continuing until a critical cluster size is attained and crystals form (Tyapkova, Bader-Mittermaier and Schweeiggert-Weisz, 2012). To prevent the erythritol that is present in monk fruit sweetener undergoes crystallisation, the author suggested that the ratio of water with monk fruit sweetener be 2:1 ratio and

avoid putting it into the fridge after it has been heated to avoid severe temperature fluctuation (Morrill, 2021).

Control has the lightness of 39.59 ± 2.92 which is lower than T1 but higher than the T2 sample. The lower lightness of control might be due to the enzymatic browning of the mango peels before being incorporated into gummy candies. According to Aslam, et al. (2014), the authors reported that mango peels consist of polyphenol oxidase and peroxidase that are rich in polyphenol causing enzymatic browning in the mango peels and this decreased the brightness of control when mango peels were incorporated into gummy candies. The sweetener used in the control was not a dependent variable because the table sugar was colourless and had no impact on the control sample's colour.

Based on the result in Table 4.1, the redness (a^*) of the T2 is the highest among the other gummy candies ($p < 0.05$) mainly due to the date fruit sweetener present in the gummy candy. According to Ashraf and Hamidi-Esfahani (2011), the colour of dates is developed by the browning reaction during the ripening, processing of dates as well as storage condition. The red to brown pigments in the dates might be generated via three mechanisms which are non-enzymatic oxidative browning of tannin, enzymatic oxidative browning of polyphenols by the polyphenolase and non-oxidative browning that involved sugar which is called Maillard browning reaction. The presence of dactyliferic acid (5-o-caffeoylshikimic acid) which is a

shikimic ester is the main component that contributed to the browning reaction during the dates' maturation. Tannins are stored in cells and transformed into insoluble particles as the colour of the date changes from green to red or yellow (Ashraf and Hamidi-Esfahani, 2011). Thus, the original colour of date fruits perceived the red to brown colour and this caused the date fruit sweetener used in the T2 sample to be more reddish and higher in redness (a^*) (10.10 ± 0.70) compared to the control (5.47 ± 1.2) and T1 (1.92 ± 0.70) samples. The lower value of a^* (redness) in control and T1 might be due to the presence of mango peels in control stated above and crystallisation of erythritol that was used in the monk fruit sweetener in the T1 sample.

The yellowness (b^*) present in control is the highest (22.35 ± 1.76) followed by T1 (20.03 ± 2.20) and T2 (18.37 ± 1.23) respectively with no significant difference ($p > 0.05$). The highest value in control is due to the carotenoid content that is present in the mango peels as well as mango juice. Marçal and Pintado (2021) stated that mango peels are generally considered a good source of carotenoids, one of the most important pigments associated with mango peels' colour, mainly yellow. Whereas T1 and T2 do not show significant differences with each other ($p > 0.05$) compared to control as both T1 and T2 consist of fewer yellow pigments in appearance due to higher whiteness and redness perceived in T1 and T2 samples.

Based on Takeungwongtrakul, Thavarang and Sa-Ut (2020), the authors conducted research on the development of strawberry gummy candy by using the reducing sugar from strawberry syrup and the results showed that the lightness (L^*) in the authors' research (30.12 ± 0.71) is lower than control, T1 and T2 in this gummy candies' research. This can explain that sucrose, monk fruit sweetener and date sweetener are suitable to be used in gummy candies production to produce a lighter colour compared to sucralose replacement gummy candies. The redness (a^*) present in Takeungwongtrakul, Thavarang and Sa-Ut (2020)'s research was higher than the samples might be due to the red colour perceived in the strawberry syrup that reflected higher red while yellowness (b^*) is less than the samples due to the absence of carotenoids in the strawberry gummy candy conducted by the authors. Another study done by Kurt, Bursa and Toker (2021) showed the gummy candies produced from natural sugars such as carob, grape and mulberry molasses gummy candies had a lower lightness (L^*) between 17.00 to 20.00 compared to the samples due to the dark colour that originally present from the Maillard and caramelisation reaction. The redness (a^*) of the molasses gummy candies are mostly the same as the control in the research while the authors reported having negative values in yellowness (b^*). This can conclude that the authors' research in molasses gummy candies was more in blue colour while the samples perceived positive values due to the presence of carotenoid in the mango gummy candies.

5.1.6 Texture Analysis

The texture is also another essential feature that determines the consumer acceptability of gummy candies (Figiel and Tajner-Czopek, 2006). Texture can be referred to as a collection of physical characteristics that are derived from food's structural components and are mostly perceived through touch. These characteristics include deformation, comminution, and creeping, all of which are caused by forces and objectively described as functions of mass, time, and distance (Figiel and Tajner-Czopek, 2006). The texture profile analysis on gummy candies was expressed in terms of the firmness while the control was doubled (80.82 N ± 14.26) of T1 and T2 might be due to the sugar which is sucrose present in the control aids in the formation and enhancement of gel strength and stabilisation. The network structure of gummy candy is stabilised by sugars through intensifying the hydrophobic reaction and hydrogen bonds and thus this provided a stable and firm gel between sugar and gelatine (Li, et al., 2019). Gok, et al. (2020) also stated that the presence of humectant (sucrose) can decrease the free water and increase hardness in gummy candy while decreasing the effect of sucrose can increase the interaction between gel matrix and gelatine chain and increase the candy's firmness. Besides, Ge, et al. (2021) stated that the presence of gelatine in gummy candies can provide a firm texture as the gelatine molecules was randomly coiled together above the gelling temperature. The helices' nucleation happened that can form a loosened network and eventually reach equilibrium through the sluggish development of independent triple helices (Ge, et al., 2021). However, the reported study by Choi, et al. (2004) indicated that the presence of sugar in a gelatine gel

could impair the gel's tensile strength and extend the polypeptide cross-linking points which were explained by a general decrease in the number of junction zones in the gelatine network (cited in Li, et al., 2019). This means that both studies met the controversial result with the gelatine gel strength when sugar was added to the samples. In another study done by Holm, Wendin and Hermansson (2009), the gel strength of gelatine was reported to increase by 7% (w/w) when the addition of sugar. This can prove that sucrose can increase the gel strength of gummy candies and thus the firmness of control made by sucrose is the highest among all gummy samples.

T1 and T2 samples have no significant difference ($p > 0.05$) as they have similar firmness between each other which were T1 (32.12 N) and T2 (34.89 N) respectively. The low value of firmness in T1 might be due to the absence of fructose or glucose in the processed monk fruit sweetener as the mongrosides present in monk fruit were being separated (Jane, 2019). Ergun, Lietha and Hartel (2010) stated that the high moisture content in T2 has greatly affected the texture of gummy candies to be softened compared to control. The lower solid content in T1 and T2 samples is also another reason that decreases the firmness of gummy candies. Delgado and Bañón (2015) further suggested increasing the drying time through dehydration and gelation process can increase the firmness of candies. The simultaneous effect between the gelling agents with water, sugar and other minor components can result in the typical firm texture of gummy candies.

5.2 Phytochemical Properties

5.2.1 Total Phenolic Content

The total phenolic content shown in Figure 4.7 stated that T2 has the highest value of total phenolic content with 69.00 µg GAE/ml among the other samples ($p < 0.05$). According to Ahmed, Aljasass and Siddiq (2014), phenolic compounds are among the most significant bioactive substances and are known for their ability to operate as strong antioxidants, hydrogen donors, reducing agents, and free radical scavengers, metal chelators, and quenching singlet oxygen. The sun drying of dates is the main cause to develop high total phenolic content as stated by Al-Farsi and Lee (2008) and Ashraf and Hamidi-Esfahani (2011). The authors further explained that the deterioration of tannins by heat, enzyme matures during the drying as well as loss of antioxidants and carotenoids can result in the releasing of phenolic compounds in the dates (Al-Farsi and Lee, 2008; Ashraf and Hamidi-Esfahani, 2011). At high temperatures, the bonds between ferulic acid and arabinoxylans and between *p*-coumaric acid and lignin may be disrupted. Thus, this can prove that dates are a good source of total phenolics when compared to the other dried fruits to be used as fruit sweeteners (Al-Farsi and Lee, 2008). The high phenolic content in T2 can be proven by Vayalil (2012) as the authors claimed that among the dried fruits, it was found that date fruit has the highest level of polyphenols, and it was six times higher than the other dried fruits. The phenolic acids that are majorly

present in date fruit were normally cinnamic or benzoic acid derivatives such as gallic acid, *p*-hydroxybenzoic, vanillic as well as ferulic acid (Vayalil, 2011).

The total phenolic content (TPC) of control is 39.00 µg GAE/ml which was slightly lower than T1 (41.00 µg GAE/ml). The study by Jahurul, et al. (2015) showed that mango peels are rich in antioxidants such as anthocyanins, carotenoids as well as polyphenols. Control that made from mango peels in gummy candies consist of high TPC might be due to the polyphenol and phenolic acid that are present in mango peels of gummy candy. According to Marçal and Pintado (2021), the dry weight of mango peels contained 1.485×10^4 to 1.276×10^5 µg GAE/ml of phenolic compounds and this amount was far more than the TPC of control. The lower TPC in control gummy candy compared to original mango peels was because only 1% of mango peels were used in the formulation of gummy candies. The authors also identified eight families of phenolic compounds while gallates, gallic acid, galotannins and xanthones are the most abundantly present in the mango peels (Marçal and Pintado, 2021). The study done by Kabir, Shekhar and Sidhu (2017) also showed the main phenolics present in mango are catechin, epicatechin, leucocyanidin as well as chlorogenic acid. Thus, this could indicate that the total phenolic content was high in the control even when only table sugar was used as a sweetener in gummy candy production. The phenolic content and antioxidant property in the mango peels remained after the freeze-drying while diminishing when using the oven-drying method, indicating that the freeze-drying method is more suitable for drying mango peels (Jahurul, et al., 2015). This can be further

supported by Dorta, Lobo and González (2012) as the authors reported the TPC of mango peels that used freeze-drying was higher than 1.2–2 times than other drying methods such as oven-drying or forced-air drying ovens. It was noted to have low polyphenolic content from oven-dried mango peels due to the degradation of phenolic compounds from chemical, thermal or enzymatic decomposition reactions from high temperature and indirectly decreases the antioxidant activity in the mango peels. The phytochemicals present in mango peels can be oxidised easily when the plant material is contacted with oxygen, and this caused low TPC in the forced-air drying oven (Dorta, Lobo and González, 2012).

The TPC in T1 is lower as compared to T2 sample which were 41.00 µg GAE/ml due to the less phenolic content present in monk fruit sweetener. According to Wuttisin and Boonsook (2019), the TPC from the monk fruit extract was 2.387×10^6 µg GAE/ml for the solid crude extract and this is a significantly higher value compared to the detected TPC in the T1 sample. A lower TPC value detected in the T1 sample might be due to the manufacturing process of monk fruit sweetener as it may undergo extraction and purification process from the monk fruit (*S. grosvenorii*) as well as additional erythritol in the sweetener. According to Younes, et al. (2019), the monk fruit extract was manufactured by extracting fruit of *S. grosvenorii* with water followed by purifying with different concentrations of mogroside V content from 25% to 55%. The least refined monk fruit extract (monk fruit extract-25%) is treated with pectinase and concentrated by resin column while the monk fruit extract that is rich with mogroside V is required to undergo a

purification process to eliminate impurities by adsorption and elution processes. The final product was concentrated to 40% soluble solids and spray-dried at 120˚C to form powder (Fry, 2012). The authors claimed that phenolic components present in monk fruit are phenolic acid, anthraquinones, alkaloids and aliphatic acids which are not major compounds found in monk fruits, and thus this can explain the low finding of TPC in the T1 sample (Suri, et al., 2020).

5.2.2 Total Flavonoid Content

The present study showed that T1 and control have significant differences ($p < 0.05$) between each other as the T1 sample consists of higher flavonoid content (680.00 µg QE/ml) than the control (359.00 µg QE/ml). According to Suri, et al. (2020) and Wuttisin and Boonsook (2019), the TFC extracted from monk fruit extract was 1.3452×10^4 µg QE/ml and the most abundant flavonoid content in monk fruit is the quercetin, kaempferol as well as vanillic acid. This showed that monk fruit extract is rich in flavonoid content while monk fruit sweetener used in this study, consisting of a mixture of monk fruit extract and erythritol may reduce the flavonoid content compared to pure extract. Only 20% of sweetener was used in the production of gummy candy which is another reason for the T1 sample detected lower levels of flavonoids than the monk fruit extract. The T2 sample was recorded at 550.00 µg QE/ml which is lower than the T1 sample due to the presence of non-flavonoids in date fruit such as cinnamic acid and benzoic acid constitute. There are some flavonoid glycosides present in date fruit such as luteolin, quercetin and

apigenin while some of the isomeric forms of flavonoids such as flavanols and flavones were present in date fruit, but the amount is not as high as in the monk fruit sweetener, and thus TFC that detected in T2 is lower than T1 (Hussain, Farooq and Syed, 2020). The benzoic acid such as gallic acid, vanillic acid and *p*-hydroxybenzoic acid while cinnamic acid derivatives such as ferulic acid and *p*-coumaric acid are under flavonoids also categorised as phenolic acids (Hussain, Farooq and Syed, 2020). The authors also stated that flavonoids are important secondary metabolites derived from polyphenolic plants that have powerful antioxidant and anti-inflammatory properties. Proanthocyanidins exclusively procyanidins and anthocyanins are also present in date fruit (Vayalil, 2012). As the date fruit sweetener originally comes from the fine ground dried date fruit as mentioned in Table 3.4 (original organic dried date powder), thus most of the flavonoid content can be preserved originally in the sweetener. The control perceived the lowest amount (359.00 µg QE/ml) of TFC as the sweetener used in the control (sucrose) did not affect TFC, but the presence of mango peels can increase the amount of TFC. According to Kabir, Shekhar and Sidhu (2017) and Oliver-Simancas, et al. (2021), mango peels consist of flavonoids, kaempferol, quercetin and catechins that might increase the TFC in the control gummy candy.

5.2.3 Ascorbic Acid Content

According to Yan, et al. (2020), ascorbic acid is a water-soluble protein that promotes healthy growth and improves iron absorption. Based on the result in Table 4.2, the average ascorbic acid content among three gummy candies was recorded at 50 mg/100 g and did not have any significant difference ($p > 0.05$) among each other. This indicates that the different types of sweeteners used in the production of gummy candy do not affect the ascorbic acid content in gummy candies. A similar result was shown in the research in Samakradhamrongthai and Jannu (2021) as corn syrup (control) was used in the production of velvet tamarind chewy candy was reported at 25.32 mg/100 g, while stevia and xylitol were used as the treatment in the authors' research have the range from 25.49 to 32.16 mg/100 g of ascorbic acid content. This can show that a less significant difference was observed by using different types of sweeteners. Monk fruit is rich in vitamin C in fresh fruit, but the percentage significantly decreased when in the dried fruit form (Li, et al., 2014). In this study, monk fruit sweetener was being used instead of the real monk fruit in the T1 sample and this caused the ascorbic acid present in the sweetener to be negligible due to the extraction and purification methods in the manufacturing of sweetener can highly destroy most of the ascorbic acid content. While date fruit sweetener that originally comes from dried date fruit contains fewer amount of ascorbic acid and this can prove that the low amount of ascorbic acid present in sweetener did not affect the overall ascorbic acid content in gummy candies (Ahmed, Aljasass and Siddiq, 2014).

5.3 Antioxidant Properties

5.3.1 DPPH Free Radical Scavenging Activity

DPPH free radical scavenging activity is the most popular, sensitive and easy method to determine the antioxidant activity of natural products without being influenced by side reactions. The basis of this assay is an unpaired valence electron on the nitrogen bridge of this N-centred radical exhibits absorbance between 515 and 517 nm and the antioxidant species neutralised the radical causing the reduction of absorbance to occur (Zihad, et al., 2021). Based on Figure 4.9, T2 has the highest antioxidant properties (85.15%) among the other samples. Ranilla, et al. (2008) stated that the presence of DPPH radical scavenging activity was related to the total phenolic content of the samples. Al-Farsi and Lee (2008) also demonstrated that date fruit sweetener consists of the highest antioxidant activity present among the carbohydrate sweeteners, which was directly connected to the sugar's phenolic content. The T2 gummy candy made from date fruit sweetener has the highest antioxidant properties even after the drying of date fruits to become date fruit sweeteners. Al-Farsi and Lee (2008) stated that the antioxidant might lose 29.7 to 42.5% after drying among three date varieties and this loss can be the result of dates' inherent antioxidants deteriorating after drying. This finding is supported by the research from Ranilla, et al. (2008) as the dates fruit sweetener had a similar percentage with T2 samples which showed 86% inhibitory against DPPH radical scavenging activity and this can claim that date fruit sweetener used in gummy candies making is a potent sweetener that provides high antioxidant scavenging

activity than other sweeteners. Hussain, et al. (2020) also stated that the presence of carotenoids, lutein and β-carotene in date fruit is the major strong antioxidant that scavenges free radicals. The reactive oxygen species (ROS) such as hydroxyl and superoxide radicals can be scavenged by the dates flesh extract that consists of high free radical scavenging activity (Ahmed, Aljasass and Siddiq, 2014). The high antioxidant properties present in date fruit are directly proportional to the total phenolic content present in the date fruit sugar that is stated in Section 4.2.1 above.

Control is perceived to contain almost similar antioxidant activity to T1 and thus they did not perceive a significant difference ($p > 0.05$). Control made from white sugar lacked phenolic compounds as they were mostly degraded during the sugar refining process, which could explain the low antioxidant activity detected in the study (Ranilla et al., 2008). The control sample showed a high value (60.94%) of antioxidant properties might be due to the presence of citric acid, mango juice as well as mango peels in the gummy candy. According to Søltoft-Jensen and Hansen (2005), the citric acid added to gummy candy production has antioxidant properties by chelating the metal ions that activate oxidation reactions. Mango juice and peels that are used in the production of gummy candies are found to be high in polyphenol and carotenoids, this can show that mango consists rich in antioxidants as a result of the high percentage of antioxidant scavenging activity recorded in the research. According to Jahurul, et al. (2015), there are two bioactive compounds which are ethyl gallate and penta-O-galloyl-glucoside present in the mango peels, and they possess the ability of hydroxyl radical, singlet oxygen as well as superoxide anions

scavenging activities. The phenolic content, carotenoids and anthocyanins present in mango peels and pulp are the major components that provide antioxidant activity as they have been demonstrated to be effective electron donors (Masibo and He, 2009). The authors also emphasised that the phenol moiety's (hydroxyl group) reactivity on the aromatic ring can scavenge free radicals via hydrogen donation or electron donation (Masibo and He, 2009).

T1 perceived 61.47% of antioxidant scavenging activity which is much lower than T2 but slightly higher than control. According to Gong, et al. (2019), the mogroside extract efficiently removes free radicals, lowers the frequency of haemolysis of Fe^{2+}, and minimizes the oxidative damage to hepatic tissues brought on by hydrogen peroxide. The *in vitro* study showed that the 11-oxo-mogroside V as well as sweet cucurbitane glycosides mogroside V are two components that consist strong ROS scavenging activity and can eliminate free radical effectively (Gong, et al., 2019). Based on Figure 4.9, the DPPH radical scavenging activity in T1 (monk fruit sweetener gummy candy) was lower than expected percentage might be due to the processing of monk fruit extract as the monk fruit was crushed to collect the juice and dehydrated into concentrated powder form and mixed with erythritol to mimic the sweetness of sucrose in the monk fruit sweetener (Jane, 2019). The cooking temperature of the sweetener to form sugar syrup in the gummy candy production is also another factor that decreases the antioxidant scavenging activity in the T1 sample. Réblová (2012) also stated that the high temperature or heating typically

accelerates the initiation processes, and this results in less antioxidant activity detected from the research.

5.4 Sensory Properties

As the confectionery items are ingested for enjoyment in addition to nourishment, taking sensory consideration into account is crucial during manufacturing (Kurt, Bursa and Toker, 2021). Overall, all sensory attributes were evaluated by 50 untrained panellists by using a 9-point hedonic scale sensory test. Five attributes of gummy candy samples which were appearance, aroma, taste, texture and overall acceptability of three gummy candies were evaluated and the scores were listed in Table 4.3. The control obtained the highest score in all attributes followed by T1 and T2 samples respectively while the control and T1 did not show a significant difference ($p > 0.05$) in aroma, taste and texture attributes. Control which is the gummy candy made with table sugar was more preferred among the other samples might be due to the general perception of the commercial gummy candies in the market. It was noted that the appearance and overall acceptability were significantly different ($p < 0.05$) among all the gummy samples, and this showed that most of the panellists preferred the appearance of control instead of T1 and T2 samples. Referring to Figure 4.5, the appearance of control is more likely to be presentable for mango gummy candies with the presence of carotenoids as natural colourant and flavouring in the mango fruit juice and peels. T1 and T2 gummy candies perceived low scores in appearance might be due to colour appearing in white (T1)

and red (T2) did not meet the yellow colour assumption of panellists towards mango gummy candies.

The control and T1 did not show a significant difference ($p > 0.05$) in aroma, taste and texture attributes as the monk fruit sweetener used in T1 gummy candy can perceive similar aroma, taste and texture properties to the control. This can indicate monk fruit sweetener is suitable to replace table sugar in gummy candies production in producing similar sensory attributes except for the appearance of gummy candy. The crystallisation of erythritol stated in 4.1.5 that leads to a white colour appearance need to be overcome to increase the acceptability of consumers. T2 gummy candy perceived the lowest scores for all attributes as the appearance, taste, texture and overall acceptability were not favourable among the panellists in using date fruit sweetener. This might because the taste of date fruit sweetener was not acceptable to some panellists when it was incorporated into the gummy candies. The texture was scored only 3.66 on a 9-point hedonic scale and this has illustrated date fruit sweetener is not able to provide chewy, gummy and firm texture as compared to commercial gummy candies on the market.

The overall acceptability in the control is the highest (7.18 ± 0.94) followed by T1 (6.54 ± 1.18) and T2 (4.02 ± 1.65) and this has pointed out that most of the panellists preferred control gummy candy rather than monk fruit and date fruit sweetener gummy candies due to the natural appearance, aroma and taste from mango fruit

and peels in the control samples. Some of the panellists also suggested increasing the chewiness and firmness of texture among all the samples while decreasing the sweetness taste in the control sample.

5.5 Limitation of the Study

In this study, sensory evaluation data were mostly obtained from the students and staff at UTAR, Kampar campus and this limited the age range and races among the panellists and indirectly affect the sensory analysis due to the respondents' similar cultures and habits. Furthermore, the total calorie content of gummy candies cannot be measured as the bomb calorimeter is still under maintenance. This analysis was critical to the overall study due to the presence of monk and date fruit sweeteners that claim to be a low or zero-calorie sweeteners. By enforcing the calorie content, it is possible to further prove and verify that the gummy candies are low or zero-calorie candies.

5.6 Further Recommendation

To obtain a more reliable and balanced result in sensory evaluation, a more variety of age groups and races are recommended in the future study of gummy candy. Besides that, the microbiological study involving plate count agar (PCA) is recommended to study the shelf life of gummy candy due to its high moisture content properties. The drying time in gummy candies should be increased to the

range of 24 to 72 hours to decrease the moisture as well as increase the firmness and chewiness of gummy candy. It is also recommended to perform sugar profile on the monk and date fruit gummy candies to show all the percentages of glucose, fructose and sucrose of gummy candies to further justify the total soluble solids content present in gummy candies.

To further improve the monk fruit sweetener gummy candy (T1), it is suggested to eliminate crystallisation by minimising the temperature fluctuations from hot gummy gel to cool temperature during the gummy candy production. The ratio used in mixing two parts of water with one part of monk fruit sweetener instead of mixing one part of water with one part of monk fruit sweetener can be implemented to remove the crystallisation process. Furthermore, a different ratio of gelling agents is suggested to use in this study to increase the hardness, firmness and chewiness of gummy candies. According to the study by Ge, et al. (2021), the mixture of different gelling agents such as pectin and agar to the gelatine can increase the network structure at the intermolecular and intramolecular levels. The authors also claimed that most of the gummy candies on the market contain more than one gelling agent that enhances the texture, appearance and sensory properties of the final product (Ge, et al., 2021). It is also recommended date fruit sweetener can be used as an alternative sweetener in other nutraceutical or functional food due to its high total phenolic content and antioxidant properties.

CHAPTER 6

CONCLUSION

In conclusion, the objectives of this study were achieved by investigating and comparing the physicochemical, phytochemical and antioxidant properties of gummy candy produced from mango (*Mangifera indica*) peels incorporated with different types of fruit sweeteners as well as to determine the acceptability of consumers toward the gummy candies. According to the study, control, T1 and T2 samples have significant differences ($p < 0.05$) in the total soluble solid content, water activity, colour and sensory analysis (overall acceptability) while the T1 sample was not significantly different ($p > 0.05$) with the control in the physicochemical analysis such as moisture content and pH value. In phytochemical analysis, T1 sample has the highest total flavonoid content while T2 sample perceived the highest total phenolic content and antioxidant properties. According to the sensory analysis of this study, the aroma, taste and texture attributes of T1 sample did not show significant difference ($p > 0.05$) with control while three gummy candies exhibited significant difference ($p < 0.05$) in the appearance and overall acceptability. In short, it can conclude that monk fruit sweetener in the T1 sample is more suitable to be used as a sugar substitute in gummy candy production to mimic the taste of table sugar and produce a healthier gummy candy. Hence, all the objectives of this research have been accomplished.

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APPENDIX

Appendix A

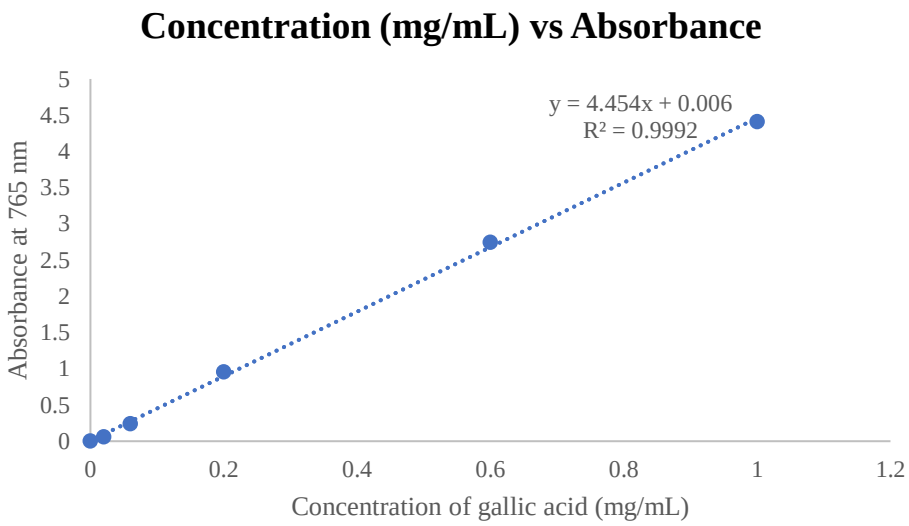

Figure 1.1: Standard curve for concentration of gallic acid (mg/mL)

Table 1.1: Concentration and absorbance of standard gallic acid

Concentration (mg/mL)	Absorbance at 765 nm
0	0
0.02	0.059
0.06	0.240
0.2	0.956
0.6	2.743
1.0	4.412

Appendix B

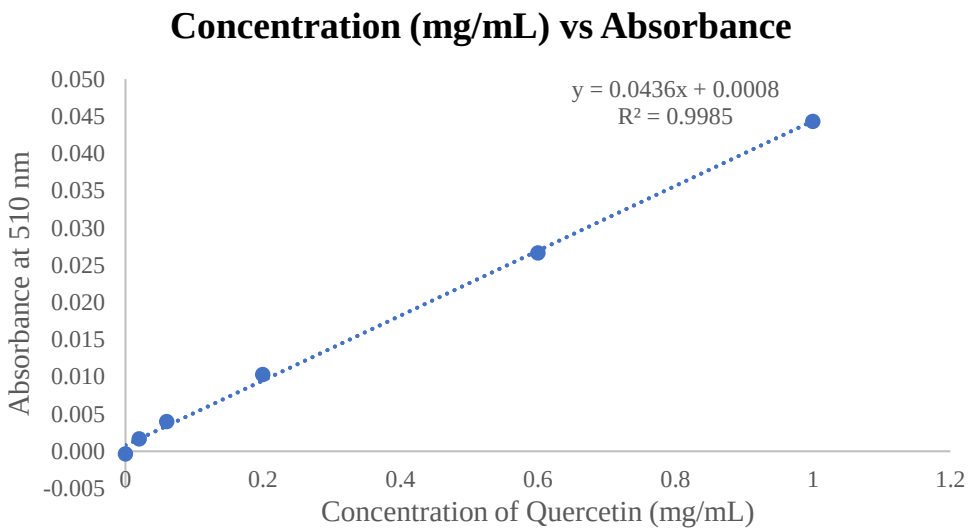

Figure 1.2: Standard curve for concentration of quercetin (mg/mL)

Table 1.2: Concentration and absorbance of standard quercetin

Concentration (mg/mL)	Absorbance at 510 nm
0	0
0.02	0.002
0.06	0.004
0.2	0.010
0.6	0.027
1.0	0.044

Appendix C

QUESTIONNAIRE FOR HEDONIC SCALE

PRODUCT: Gummy candy

Please evaluate the three gummy candy samples in the following order. Taste and tick the likeliness of each sample in terms of different characteristics. Please rinse your mouth with water before tasting each sample.

NAME: _____ DATE: _____

9-point hedonic scale

Dislike extremely (1)
Dislike very much (2)
Dislike moderately (3)
Dislike slightly (4)
Neither like nor dislike (5)
Like slightly (6)
Like moderately (7)
Like very much (8)
Like extremely (9)

Characteristics / Code	549	716	832
Appearance (colour)			
Aroma			
Taste (sweetness)			
Texture			
Overall acceptability			

Comments:

_____

Thank you.

Figure 1.3: Questionnaire for 9-point hedonic scale

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Programme / Course	Bachelor of Science (HONS) Food Science
Title of Final Year Project	Physicochemical, phytochemical and sensorial quality of gummy candies produced from mango (*Mangifera indica*) peels with different types of fruit sweetener

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